



International Baccalaureate Organization

IBAP

Teacher Training Workshop

Chemistry

Carol Jordan

INTERNAL ASSESSMENT

Vade Mecum

Group 4

Experimental sciences

Contents

4.1	Publications.....	1
4.2	Summary of arrival dates: May and November 2007 sessions	1
4.3	Internal assessment requirements.....	1
4.4	Documentation relating to internal assessment.....	2
4.4.1	Practical scheme of work	2
4.4.2	Assessment.....	3
4.4.3	The group 4 project.....	3
4.5	Samples for moderation	4
4.5.1	The purpose of moderation	4
4.5.2	Indicating pieces of work to be re-marked.....	4
4.5.3	The final mark for internal assessment	4
4.6	Design technology.....	5
4.6.1	Requirements	5
4.6.2	Final assessment.....	5
4.6.3	Samples for moderation	5
4.7	Internal assessment checklist for all subjects (except design technology).....	6
4.7.1	Before the completion of internal assessment activities	6
4.7.2	Before the submission of the sample work	6
4.8	Summary of the coordinator's requirements.....	7
4.9	IB data booklets	7
	Form 4/IA.....	9
	Form 4/IADT	11
	Form 4/PSOW.....	13
	Form 4/PSOW Sample.....	15



International Baccalaureate Form 4/IA

Internal assessment cover sheet: group 4
(except design technology)

SUBMIT TO: **MODERATOR** ARRIVAL DATE: **20 APR / 20 OCT** SESSION:.....

SCHOOL NUMBER:

0	0				
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SCHOOL NAME:

Please check (✓) the boxes below to confirm that you have carried out the following requirements in preparing the sample.

- ☐ I have read section F6 to F16 and section 4 in the *Vade Mecum*.
- ☐ Internal standardization has taken place where two or more teachers are responsible for the internal assessment of candidates.
- ☐ A form 4/PSOW is included for each candidate in the sample set.
- ☐ Evidence of participation in the group 4 project is included for each candidate in the sample set.
- ☐ Photocopied material is legible (ideally, original work should be sent to the moderator).
- ☐ The criteria P1 (a), P1 (b), DC, DPP, CE, MS, PS (a) and PS (b) have all been assessed on at least two occasions.
- ☐ The two highest levels for each of the criteria P1 (a), P1 (b), DC, DPP and CE, have been clearly circled or highlighted on each candidate's 4/PSOW.
- ☐ The corresponding write-ups/reports and teacher instruction sheets for each candidate in the sample set are clearly identified.

No written evidence is required for PS (a) and (b) and MS.

The final mark out of 48 for internal assessment must be recorded on the internal assessment option on IBIS.

Atypical candidates

It is important that the sample work received by the moderator is typical of the marking standards applied to the whole group of candidates. If IBIS selects a candidate's work for a moderation sample that is atypical, include the work of another candidate with the same or a similar mark in addition to that candidate's work.

I confirm that, to the best of my knowledge, the write-ups/reports submitted are the authentic work of each candidate.

Teacher's name: Date:

Teacher's signature:



International Baccalaureate Form 4/PSOW

Internal assessment cover sheet: group 4

SUBMIT TO: MODERATOR

ARRIVAL DATE: Apr. 10, 2005

SESSION: May 2005

SCHOOL CODE:



SCHOOL NAME: [Redacted] International School

* Type or write legibly using black ink and retain a copy of this form.

SUBJECT: Chemistry

LEVEL: Standard

CAND NAME: David Willis

CAND NO: 0134 088

Date(s)	Outline of experiments/investigations/projects (include title, a brief description and internal school coding if used)	Topic/ option	Time (hrs)	Levels awarded					PS(a)	PS(b)
				PI(a)	PI(b)	DC	DPP	CE	MS	
1-Sep	1. Observing the Spectra of Elements	2.1	1							
17-Sep	2. Identifying Oxidation States of Cations	4.1/ 10.1	1.5							
14-Oct	3. Determining the Empirical Formula of MgO	1.2	1.5							
5-Nov	4. Peanut Oil Extraction: Part 1 - Testing Solubility of Polar and Non Polar Substances	4.5	1							
8-Nov	5. Peanut Oil Extraction: Part II - Extraction of Peanut Oil From Peanuts	4.5	1						3	2
15-Nov	6. Investigating Charles Law	5.1	2			1	1	1	2	2

* Design technology: the highest level attained in each criterion in investigations and the level attained in each criterion for the design project.

Two highest levels achieved*:

2	1	2	3	2	3	2
1	1	3	3	1	2	3

TOTAL

35

This total must also be entered on IBNET

To be completed by teacher

Name: [Redacted]

Signature: [Redacted]

Date: April 8th, 2005

International Baccalaureate

Form 4/PSOW (Reverse)

SCHOOL NAME: **International School**

SUBJECT: **Chemistry** LEVEL: **Standard** CAND NAME: **David Willis** CAND NO: **0134 088**

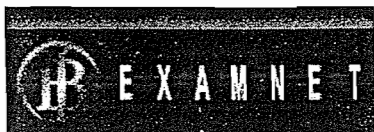
Date(s)	Outline of experiments/investigations/projects (include title, a brief description and internal school coding if used)	Topic/ ption	Time (hrs)	Levels awarded					
				PI(a)	PI(b)	DC	DPP	CE	MS
1-Dec	7. Molarity: Preparing Solutions of Copper(II) Sulphate	5.1	2						
30-Nov	8. Determining the Molar Volume of Hydrogen	1.4	2			0	0	0	2
12-Dec	9. Reactions of CuCl ₂ : Limiting Reactant and Percent Yield	1.4	1						
25-Jan	10. Determining the Specific Heat of a Metal	6.1	1.5			2	3	2	2
2-Feb	11. Heat of Neutralization	6.2	1.5						
15-Feb	12. Modelling Rates of Reactions	7.1	1.5						
7-Mar	13. Planning Lab: Kinetics of a Chemical Reaction	7.2	1	2	1				
14-Mar	14. Modelling Equilibrium	8.1/ 8.2	1.5						
Feb-Mar	15. Group IV Project: Science of the Sport	Grp IV	15	1	1			3	1
21-Mar	16. Strong Vs. Weak Acids and Bases	9.1/ A.5	1						
5-Apr	17. Titration of a Weak Acid with Strong Base	9.2/ 9.5	1.5			3	3	1	3
apr	18. Creating an Activity Series of Metals	10.2	1.5						

Form 4/PSOW (Reverse)

International School

CAND NO: 0134 088

[illegible]



IA Feedback form

Session: May 2006

Short cuts

Form 4/IAF

IBIS

Internal assessment feedback form: group 4

My password Exam session Site language External links

Session: MAY 2006

School:

Subject: CHEMISTRY (HL/SL) PRACTICAL WORK in ENGLISH

Name of teacher/s

Frequently asked questions

A CLERICAL/PROCEDURAL

- 1 Was the form 4/PSOW submitted for each candidate completed correctly?
- 2 Were the two highest levels circled/highlighted on the form 4/PSOW for each sample candidate?
- 3 Were written instructions or outlines of verbal instructions included?
- 4 Was there evidence of participation in the group 4 project for each sample candidate

About Acrobat

Terms & Conditions

B COMMENTS TO TEACHER(S) ON SAMPLE WORK

Intellectual Property of the IBO

- 1 Were the investigations/projects appropriate for the assessment of particular criteria? If NO, please complete section C below
- 2 Was the practical programme of the correct duration(40hrs SL, 60hrs HL)?
- 3 Was the syllabus coverage (Core, AHL, Options) appropriate?
- 4 Was the practical scheme of work of suitable complexity?

IA Feedback form

ADDITIONAL COMMENTS

Even though it is not necessary to carry out an investigation for each topic, the balance of investigation enhanced with the addition of an organic chemistry and options labs. It would be helpful to the moderator awarded for each aspect is included as well as teacher comments made to students during grading. The t scores were not circles for each criterion. For two students only one piece of evidence for PI(a) was included students had incomplete sample sets, where the labs circled for moderation were not included. It is not ne send to the moderator all the investigations in the practical program, only those flagged for moderation are Evidence of individual contribution to the Group 4 Project was not included for every student. This must be candidate in the sample.

The samples sent demonstrated a lack of familiarity with the requirements to fulfil the criteria. Many of the this report were previously identified during the M05 session. On occasions students were given credit for they were not present. The TSM 1 and 2 has examples of suitable investigations and the OCC provides a to network with other teachers and access ideas for labs.

DC involves the collection of raw data. To achieve a level 3 students need to incorporate uncertainties into quantitative data has been recorded.

For CE, aspect one student must interpret and explain the results and compare with the literatures value. In aspect two, students' sources of error need to be discussed. For aspect three, improvements need to be that need are specific (not vague), realistic and would lead to significant improvement in experimentation. involve available equipment or materials. The improvements should relate to the cited sources of error in :

C DETAILS OF UNSUITABLE INVESTIGATIONS

Name of investigation(s) not suitable for assessing PI(a) and reasons why

Collecting hydrogen gas, Preparing carbon dioxide gas and Density Labs. Students must form their own question that is significantly more precise than the general focus the teacher has provided to achieve a level one. In these labs students were provided with too much information resulting in each student writing identical

teacher. These tasks are also not demanding enough for hypothesis generation because it only allows for explanation, for example students predicting the number of moles of magnesium used in the reaction. The investigations for PI(a) involve those with potentially two independent variables. Where the teacher title is a problem and only one or no variable can be manipulated the task is more suited to PI(b).

Name of investigation(s) not suitable for assessing PI(b) and reasons why

Collecting hydrogen gas lab. For aspect one students must choose their own equipment and chemicals are provided by the teacher. Because each student produced the same method, the scope of this task is an assessment of PI(a).

Name of investigation(s) not suitable for assessing DC and reasons why

Coffee Cup Calorimeter and Solubility Product labs. If students are given a fill in the box data collection 3 can't be awarded. Investigations best suited for assessment of this criterion allow students to collect data of complexity to demonstrate a full range of data collection skills. These include the collection of qualitative data, recording absolute uncertainties and units and showing consistency with decimal places in addition to presenting their own tables.

Name of investigation(s) not suitable for assessing DPP and reasons why

Percentage of acetic acid in vinegar and solubility product labs. If students are given structured questions have been told what variables to plot on a graph a level 3 can't be awarded. Investigations best suited for this criterion allow students to construct their own graphs, carry out calculations and demonstrate that they propagate uncertainties and express uncertainties as fractions and percentages.

Name of investigation(s) not suitable for assessing CE and reasons why

Observing the reaction between carbon dioxide and sodium hydroxide. Investigations susceptible to systematic errors are the most conducive to meeting the needs of aspects two and three.

Please note that the moderator completing this feedback form cannot comment on the accuracy of (s') marking as the moderator is also subject to moderation.

<< Previous

Next >

May 2005

Chemistry SL/HL Internal Assessment

1. Strengths and weaknesses of the work

Strengths:

Feedback to candidates using the c, p, n notation for each aspect was useful and of great help to the moderator. Students have been given constructive feedback on their marked work.

Weaknesses:

Four of the moderation samples were incomplete. One student was missing an investigation flagged for CE and two of the four samples did not have evidence of the group four project. These arrived promptly when requested. Evidence of individual participation in a Group 4 Project for every student in the sample is required. One small clerical error was made where the level on the 4/PSOW did not match the level awarded on the students paper. The signature of the teacher was omitted from the 4/PSOW forms. It is helpful if the assessments are organized in the order shown on the 4/PSOW.

The moderation task would be made easier if fuller teacher instructions were provided. Please don't select work for moderation where the teacher's instructions are not available as was the case with the acid-base titration lab. The more information the teacher provides with respect to the sampled investigation the more likely it is that the moderator's marks will fall in line with theirs.

2. Suitability of the task set

The investigations included in the moderation sample showed a varied practical program, with tasks of suitable complexity and level of difficulty. The investigations chosen were for the most part suitable for the relevant assessment criteria chosen.

3. Application of the criteria

In general, the assessment criteria were applied correctly.

4. Accuracy of Assessment

The assessment was mostly at the correct level with some inconsistencies which are outlined below. The assessment of the accuracy falls into two areas, the suitability of the task and the appropriate application of the criteria.

Pl(a)

In the enthalpy of a reaction lab, insufficient teacher material was provided outlining the general focus given to the students. The four students' research questions all used the same chemicals, suggesting that they had been given a much more specific research question. If the problem or research question is provided the maximum moderator can give is a level two.

Likewise, in the hydrolysis of halogenalkanes lab, the research question had not been sufficiently modified by the students and therefore was unable to score a level three. A more focused aim would have included details of the measured and manipulated variables.

In the enthalpy of a reaction, hydrolysis of halogenalkanes and thermometric titration labs, the hypotheses were not explained at the level of depth required for HL nor at a molecular level and therefore students could not achieve a level three for aspect one.

For aspect three all independent and dependent variables need to be specifically listed and not inferred in PI(b) to achieve a level three. In the enthalpy of change, thermometric titration and group four project students did not write a complete list of all the important controlled variables.

PI(b)

In the enthalpy of a reaction lab each student used the same materials, quantities, concentrations and apparatus. If the students have been told what apparatus and materials they require, the maximum the moderator can award is a level two. In aspect two students are required to design a method that allows for the control of variables. In the enthalpy change lab, all four students had the same method, suggesting that they had been provided with too many details. If the specific instructions are provided students can't achieve a level three for aspect two. For this aspect each student should produce a different response.

DC

The hydrolysis of halogenalkanes lab is not the most suitable assessment for evidence of this criterion because it does not allow students to demonstrate the full range of skills required. These skills are presentation of quantitative and qualitative data, recording of absolute uncertainties and units, and demonstrating the correct use of decimal places and significant figures. One student recorded only a very small number of qualitative observations, whilst three others had detailed qualitative observations but did not record absolute uncertainties. Two students produced exactly the same response. For a level three each student should present their own work.

Students need to be careful that all the appropriate data is recorded. For example in the acid-base titration lab changes in the color of indicators at the end point and the colors of solution must be recorded for a level 3 for aspect one. Tables should also be clearly formatted, and have a layout that eases interpretation for a level three for aspect two. Students would have benefited from a little more assistance on how to correctly draw and layout more complex tables in Words like those used to present titration data.

DPP

To achieve a level three for aspect one graphs need to be formatted correctly if Excel is used. This includes using an appropriate scale for axes, descriptive titles, and clearly plotted points and legends. Extrapolated points should be clearly shown.

For aspect two all HL students should endeavor to propagate experimental uncertainties and calculate the percentage error when literature values are available. These calculations can then be used to discuss the sources of error in the conclusion and evaluation. Examples where error analysis could have been attempted were in the thermometric titration, enthalpy of a reaction, alcohols and fuels and Avogadro's theory investigations.

CE

For the most part the discussions and suggestions for improvement were too simplistic for HL and a level three for aspects two and three. The student evaluations did not reflect the high level of understanding of systematic and random error, their causes, and effects and how to minimize them.

5. Recommendations for further improvement

This is a good balanced practical program with a consistent standard of marking. Aspects to consider for future years include:

1. Ensure sufficient teacher instructions (written and/or oral notes) are provided with each assessment sent in the sample.
2. For Pl(a) provide students with only a general question, which gives them sufficient scope to focus it further.
3. Ensure that the hypothesis is explained at a level of depth and understanding expected for HL students.
4. When identifying variables, all the independent and dependent variables need to be specifically listed and not inferred in Pl(b).
5. For Pl(b) don't provide students with a specific list of the materials and chemicals to use.
6. All Pl(a) and Pl(b) assessments should be completed by each student independently.
7. For DC choose investigations for moderation that best allow students to demonstrate the full range of skills.
8. Assisting students with the correct layout of tables in Word and formatting of graphs in Excel.
9. HL students should attempt to propagate experimental uncertainties and wherever possible compare their result with literature value and determine the percentage error/difference.
10. Discussions how to improve an investigation needs to be of sufficient complexity for HL and reflect a high level of understanding of systematic and random errors, their cause effects and how to minimize or eliminate them.

For Pre-August
2007
Guide

A good sample set for moderation will . . .

1. meet the deadline for arrival at the moderator.
2. be well organized with lab reports arranged in the order that they are written on the 4/PSOW.
3. provide feedback to students using the c, p, n notation for each aspect.
4. show evidence that useful information about each lab has been given to the students.
5. show evident that the students have been given constructive written feedback by teacher.
6. demonstrate a good breadth and depth and show that the full range of practical skills have been developed.
7. include all the instructions given to students.
8. have no clerical errors on the 4/PSOW. Common errors include: not all the work for moderation is flagged, the two highest grades are not flagged, there is no evidence of the group 4 project, the cover sheet is not signed by the teacher.
9. indicate the level awarded for each aspect (rubrics) is given and rationale where necessary.
10. arrive promptly to the moderator.
11. include details of the investigation topics/options and their duration for the whole practical program.
12. include 40h of lab work for SL and 60h for HL. This includes up to 15h on the Group 4 Project.
13. represent a reasonably balanced practical program. According to the Chemistry guide "The range of investigations carried out should reflect the breadth and depth of the syllabus at each level, but it is not necessary to carry out an investigation for every syllabus topic."
14. represent a course of work of sufficient complexity for SL or HL.
15. respect safety and ethics.
16. show evidence of individual participation in a Group 4 Project for every candidate in the sample. Identical written copies of write-ups are not acceptable.
17. highlight clearly the highest two levels awarded per criterion on the 4/PSOW of each candidate. This should also appear at the bottom of the form in the boxes.
18. be accompanied by relevant lab instructions (photocopied sheets, notes of oral instructions) for each investigation circled / highlighted levels on form 4/PSOW. The more information they give with respect to the sampled investigation the more likely it is that the moderator's marks will fall in line with theirs.
19. include written evidence of PS (a), PS (b) and MS.

Note:

You are not required to submit a complete portfolio for each student in the sample set, just the assessments flagged for moderation.



Common problems with IA are . . .

1. PI (a)

1. The teacher provides a research question that can't be sufficiently modified by the student.
2. Students have an identical research question.
3. The hypothesis is stated but not explained or not explained at the correct level. For example an investigation into the rate of a reaction is not explained at a molecular level using collision theory.
4. Hypothesis does not involve the manipulation of two or more independent variables.
5. Independent and dependent variables are not evident.
6. Students are given the independent and dependent variables and told what variables to hold constant.
7. Lab is not suited to the criterion, because it does not allow the independent variable to be manipulated. For example making a buffer solution or determining the pH of household substances.

2. PI (b)

1. Teacher provides students with the method
2. Teacher provided the students with the complete list of all the equipment and chemicals.
3. A separate list of materials is not given and they are not made clear in the method.
4. Concentration of chemicals used not stated.
5. Control of variables is not explicit.
6. Students have identical responses.
7. Chemical reactions involving stoichiometry do not indicate the amounts of substances used and steps involved.
8. Students do not investigate a sufficient number of manipulated variables, for example three different temperatures in a rate investigation or collect data over time.
9. Students are told how to collect the data and how much data to collect.

3. DC

1. Qualitative data is not recorded when clearly present e.g. changes in the color of indicators at the end point of a titration, colors of solutions.
2. Absolute uncertainties not recorded in data tables.
3. Significant figures in the +/- uncertainty and measured data is not consistent.
4. Incorrect or missing units.
5. Incorrect number of decimal places and/or inconsistency with significant figures.

6. The task is too simple to meet the demands of the criteria. DC should demonstrate a student's ability to collect qualitative and quantitative data, recording absolute uncertainties and units, show consistency with decimal places, design and present tables.
7. Teacher has provided formatted data tables for students to fill in.

4. DPP

1. Incorrect use of significant figures in calculations. For example the level of precision in the processed data is not consistent with the raw data.
2. Incorrect lines drawn in graphs for data e.g. straight or curved line.
3. Teacher has provided too much information on how the data is to be processed e.g. a set of prescribed steps or too much assistance in how to format graphs.
4. Electronic graphs are not formatted by student.
5. Graphs do not aid interpretation of the data.
6. HL students have not carried out error analysis / propagation of errors. Not marked down at this stage if not perfect but a reasonable attempt needs to be made.
7. SL don't quantify final uncertainty in a numerical way. For example % error if literature value is available.

5. CE

1. Investigation is not susceptible to systematic error.
2. Results not compared to literature values.
3. Results are just restated rather than explained.
4. Structured questions are given by teacher.
5. Not all possible sources of reasonable systematic errors are noted. Ran out of time is not a reasonable source of error.
6. Improvements are not based on the systematic errors noted.
7. Improvements are trivial and will not lead to significant improvement in experimentation.
8. Improvements involve equipment or materials not easily available.

Name:

Date:

Investigation Title:

Aim

In defining the research question describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

Hypothesis

In formulating the hypothesis describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

Selecting variables

In selecting all the dependent and independent variables describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

Materials List

When making a list of the apparatus or materials (or labeled diagram) describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

Method

In designing a method to control the independent variables describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

In designing a method that collects sufficient relevant data describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

Data Collection

When collecting and recording the raw data describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

When organizing and presenting the raw data describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

Data Processing and Presentation

When processing the raw data describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

When presenting the processed data describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

Conclusions

When drawing conclusions describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

Evaluation

When evaluating the procedure(s) and results describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

When suggesting improvements describe one aspect where you met the criteria and one aspect where you did not meet the criteria. Explain.

Name: _____

Date: _____

Lab Title: _____

1. Describe the new practical skills/ personal skills and/or new knowledge did you acquire when carrying out this lab.
2. State the criteria used to assessed the lab report - Planning, Data Collection, Data processing and Presentation, Conclusion and Evaluation.
3. Describe your weaknesses? In other words where did you lose points? Be specific.
4. Describe your strengths
5. If you could improve your performance in each of the individual criteria what would you change or do differently?
6. What sort of extra assistance would you seek next time you complete a lab report?

(Keep this reflection in the internal assessment part of your binder and refer to it next time you write a lab report)

Name: _____ Date: _____ Lab Title: _____

For each of the questions below give yourself a score or either c, p, n or NA.

C	if you do this all of the time
P	if you do this most of the time
N	if you don't do this at all
NA	if this criterion is not appropriate for this investigation

Manipulative skills		
(a) Carries out techniques safely		C,P,N,NA
1.	Measures quantities using the most accurate measuring device available for the type of measurement.	
2.	Minimizes systematic errors and uncertainties when making measurements. For example: reading and using scales correctly, making sure electronic equipment is calibrated before use, minimizing parallax error when reading a meniscus, recording the correct end point in titrations, and minimizing fluctuations on electronic devices.	
3.	Assembles and uses equipment correctly, safely and confidently.	
4.	Wears safety glasses and lab apron as required.	
5.	Washes hands after using chemical substances in the laboratory.	
6.	Takes care not to contaminate different chemicals.	
(b) Following instructions		
1.	Reads/listens to instructions before asking for help.	
2.	Only starts the investigation after having read/listened to all the instructions.	
3.	Can follow instructions with direct little assistance.	
Personal skills (a)		
(a) Working within a team		
1.	Shows responsibility in the group by meeting deadlines and taking shared responsibility for mistakes and failures.	
2.	Accepts a fair share of responsibility for the planning, carrying out lab, reporting, cleaning up, organising the equipment and collecting / recording data outside of class. Does not to evade individual responsibility.	
3.	Allows other to contribute their strengths to the task.	
4.	Avoids dominating the group and/or ignoring and criticizing members.	
5.	Shares equipment and materials with others when required.	
(b) Recognizing the contributions of others		
1.	Encourages others to share their ideas.	

Manipulative skills and personal skills (a) and (b)

2.	Gives verbal support and acceptance of the ideas of others.	
3.	Asks for help from others when needed.	
4.	Avoids immediate rejection, ridiculing or criticism of the ideas of others.	
(c) Exchanging and integrating ideas		
1.	Gives (or encourages others to give) positive verbal feedback on the progress of the experiment.	
2.	Asks others to clarify their ideas and/or make their reasoning explicit.	
3.	Asks critical questions in a way to improve understanding.	
4.	Seeks to integrate the ideas of others into a single unified plan.	
5.	Expands on the ideas of others.	
6.	Avoids insisting his/her ideas be followed.	
Personal Skills (b)		
(a) Approaching scientific investigations with self-motivation and perseverance		
1.	Shows an interest in the topic being investigated.	
2.	Asks teacher/peers when he/she has doubts.	
3.	Makes more measurements / trials than originally planned, when they seem out of order.	
4.	Hands in lab report on time.	
5.	Takes care and time in the presentation of the report.	
6.	Is willing to work outside of class time when required.	
7.	Takes responsibility for cleaning up work area and putting away materials and equipment without having to be asked.	
(b) Working in an ethical manner		
1.	Handles equipment carefully so as not to cause damage.	
2.	Reports when equipment has been broken.	
3.	Refrains from copying the work of others. Records own data in lab journal. Does not share electronic files or hardcopies of work.	
4.	Cites bibliographical sources for information used.	
5.	Presents all the data collected in lab report. Explains the reasons for excluded trials. Does not 'fudge' results to make them look good.	
(c) Paying attention to the environmental impact		
1.	Avoids wasting chemicals.	
2.	Cleans spilled chemicals or broken glassware immediately and appropriately.	
3.	Washes and cleans up glassware and equipment after use.	
4.	Disposes of chemicals in a suitable manner as directed by the teacher	
5.	Shows awareness of the impact of the chemicals on the environment and their health effects.	

Teacher Instructions



Water Pollution

Produce a plan for an investigation into some aspect of water pollution / quality studied in the Environmental Chemistry Option.

Assessment

Planning (a) and Planning (b)

Steps:

1. Define a focused problem or research question
2. Formulate a hypothesis
3. Select the relevant dependent and independent variables
4. Outline a procedure for both the control of the variables and the collection of data to test your hypothesis.

PI(a)

Me	
Teacher	
Moderator	



May 23, 2006
Henrik Rydh, Carson Lee

The Effect of Temperature on the Level of Dissolved Oxygen in Distilled Water

Planning (a)

Research Question: The purpose of this investigation is to determine the effect of temperature on the concentration of dissolved oxygen in a sample of distilled water. ✓

Hypothesis: It is predicted that the level of dissolved oxygen in a body of distilled water will decrease as the temperature of the water is increased. There will be an inverse relationship between temperature and oxygen concentration. The premise of this hypothesis is the understanding that the process of dissolving is exothermic. Therefore, a dynamic equilibrium system is established between the concentration of dissolved oxygen and the concentration of free oxygen in the air. Because of the nature of the dynamic equilibrium, when the temperature of the distilled water is decreased, the equilibrium will shift in the direction of the dissolved oxygen due to the exothermic nature of the dissolving process. In concordance with Le Chatelier's principle, the position of equilibrium will shift in a manner that resists the changes placed upon the equilibrium. Therefore, the levels of dissolved oxygen will increase. By similar principle, when the temperature of the distilled water is increased, the equilibrium will shift in an endothermic direction, resulting in a lower concentration of dissolved oxygen due to a shift in the equilibrium away from the direction of the dissolved oxygen.

show with equations

Dependent Variables:

- The concentration of dissolved oxygen present in a sample of distilled water at a

All citations refer to:

Vernier Software & Technology. "Dissolved Oxygen Probe." 14 February 2005.

<<http://www2.vernier.com/booklets/do.pdf>>.

General Chemistry Online. "How Can I Predict Oxygen Solubility In Water?" 20 September 2005. <<http://antoine.frostburg.edu/chem/senese/101/solutions/faq/predicting-DO.shtml>>.

designated temperature.

Independent Variables:

- The temperature of the sample of distilled water.

Controlled Variables:

- 200 ml of distilled water will be used for each reading.
- Barometric pressure: 765 mm Hg
- Air temperature: 22° C ✓
- Same apparatuses used throughout experiment (see Materials)

Planning (b)

Materials:

- CBL System
- CBL power adapter
- TI Graphing Calculator
- CHEMBIO program
- Vernier Dissolved Oxygen Probe
- Calculator-CBL link cable
- 250 ml beaker
- Dissolved Oxygen Electrode Filling Solution
- Sodium Sulfite Calibration Solution
- Distilled water
- Paper towels
- Pipet
- 100% calibration bottle
- Ice
- Heating plate
- Mercury Barometer



Planning 1(b)



Design an experiment to test the following hypothesis

The rate of a chemical reaction will double if the temperature is increased by 10°C

2

Pl(b)

Me	
teacher	1
moderator	

Lab planning 1b

Experiment A

Hypothesis: A 10°C rise in temperature doubles the rate of reaction

Materials:

- Waterbaths
- 1% amylase solution
- 1% starch solution
- Iodine
- Test tubes
- Pipette
- 10ml measuring cylinder
- Time watches

Method:

- Prepare 5 test tubes and label them
- Measure and add 10ml of 1% starch solution to each test tube
- Add two drops of iodine to each test tube
- Measure and add 2 ml of 1% amylase solution to each test tube
- Place each test tube in waterbaths with different temperature of water (0°C, 10°C, 20°C, 30°C and 40°C)
- Observe and record the amount of time taken for each solution to change color from black/purple to light brown/yellow (color of iodine)

Controlled variables:

- The amount of amylase solution added
- The amount of starch solution added
- The amount of iodine added

Independent variables:

- Temperature of water

I will collect the amount of time taken for each enzyme reaction to be completed at different temperatures. I expect the enzyme reaction taking place at 40°C will be take the shortest time for starch to break down into simple sugar molecules while that at 0°C will take the longest time. If the hypothesis is correct, the amount of time taken for completing the enzyme reaction at 10°C will be half the amount of time taken at 0°C, the time taken at 20°C will be half of that at 30°C and so on.

Internal Assessment Marking Form

Criterion: Planning 1b

April 2005

2

Student:

10°C doubles Rate

Appropriate apparatus/materials are selected (diagrams may be acceptable).	
This will give an indication. The choice of an enzyme reaction limits the temperature range that can be used	c (p) n
A realistic method that allows for the control of the variables is designed.	
	c (p) n
A method that allows for the collection of sufficient relevant data and excludes the collection of irrelevant data is designed.	
This will give a single pair of results. Better would be a method which allows a graph to be drawn	c (p) n

ccc	3
ccp ccn cpp	2
(ppp) ppn cnn ppn	(1)
pnn nnn	0

GRADE	
-------	--

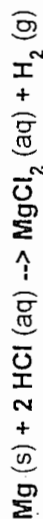
The Molar Volume of a Gas

Purpose: To determine experimentally the molar volume of hydrogen gas by measuring the volume of hydrogen gas produced by a given mass of magnesium metal.

Theory: According to Avogadro's hypothesis equal volumes of gases measured under the same temperature and pressure contain equal numbers of molecules. As a result the masses of gas volumes are in the same ratio as the masses of their constituent particles.

The volume of gas chosen for comparison is the volume occupied by one mole of a gas. However, the volume of a gas depends on the pressure and temperature of the gas. To keep the comparison on the same basis a standard temperature of 0°C or 273 Kelvin and a standard pressure of 101.3 kPa (760 mm of mercury) have been chosen. Under these conditions the volume of one mole of gas is 22.4 dm³.

In this experiment you will determine the standard molar volume of a gas. You will react a known mass of magnesium metal with excess hydrochloric acid and collect the hydrogen gas generated over water in a gas collection tube. The chemical reaction for this process is:



The gas collected will be saturated with water vapor and it will be at conditions other than STP. If the level of gas in the collection tube is not equal to the level of water in the reaction beaker, the gas in the gas collection tube is not at atmospheric pressure. It is necessary to make the appropriate correction.

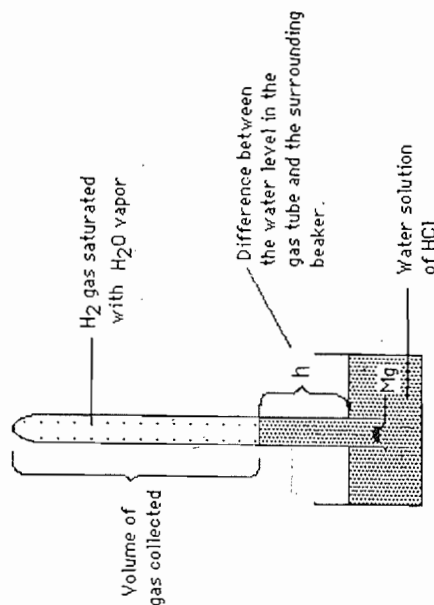


Figure 1
Gas Collection Apparatus

If the level of the water in the gas collection tube is not equal to atmospheric pressure the difference in pressure can be determined by dividing the difference in levels by the specific gravity of mercury, 13.6.

P tube = (Patmospheric - difference in levels) / 13.6

Since the hydrogen is collected over water it is necessary to correct for the vapor pressure of water. Using Dalton's Law, one can assume that the total pressure in the tube is the sum of the partial pressures of hydrogen and water vapor. Hence the pressure of hydrogen in the tube is can be determined by subtracting the vapor pressure of water at the temperature of the gas in the tube.

$$P_{H_2} = P_{\text{tube}} - P_{H_2O}$$

The volume of gas collected at STP can be calculated from the adjusted pressure, the observed volume, and the ambient temperature using the universal gas equation. The number of moles of hydrogen can be calculated from the number of moles of magnesium used to generate it. The standard molar volume can then be calculated by proportion using the number of moles of hydrogen gas and the volume occupied at STP by the hydrogen.

Apparatus

Barometer 1026 kPa 30.31 in Hg
 beaker
 Magnesium ribbon
 Thermometer
 10 mL graduated cylinder
 copper wire
 ring stand
 1 hole rubber stopper
 6M HCl solution
 utility clamp
 ruler
 gas collection tube safety glasses

Procedure

Procedure

1. Put on your safety glasses.
2. Record the barometric pressure and the room temperature. Obtain and record the mass of 1.00 meter of magnesium ribbon.
3. Obtain a piece of magnesium approximately 25 mm long. Measure the length of ribbon to the nearest 0.5 mm and record the value.
4. Obtain a piece of fine copper wire approximately 10 cm long. Roll the magnesium in a small ball and encase it in a cage of copper wire. Be sure to leave several centimeters of copper wire extended from the cage. This handle will allow the ball of magnesium to be attached and anchored at the mouth of the gas collection cylinder.
5. Assemble the ring stand and utility clamp to hold the gas collection apparatus.
6. Add approximately 300 cm³ of tap water to the 600 cm³ beaker.
7. Carefully add 10 cm³ of 6 M hydrochloric acid to the gas collection tube. Incline the tube slightly and continue filling the tube with tap water from the 600 cm³ beaker. While pouring the tap water in the tube try to rinse down any acid that might have remained on the sides of the tube. Avoid agitating the bottom acid or the interface between the water and the acid if possible. Attach the magnesium package encased in copper wire at mouth of the gas collection tube. Insert a one hole rubber stopper to hold the magnesium ball in place. Be sure that the tube is filled to capacity so that the rubber stopper must displace water to be inserted. Be careful not to trap any air bubbles in the tube.
8. Cover the stopper hole with your finger and immediately invert it into the beaker containing the water. Your apparatus should look like figure 1. Secure the gas collection tube with the utility clamp so that the rubber stopper is slightly above the bottom of the beaker. Allow the chemical



reaction to continue until no more gas is generated. When the reaction has stopped, allow the apparatus to cool 3-5 minutes so that it is at room temperature.

9. Measure the volume of gas generated using the scale on the gas collection tube and record this.
10. Measure the difference in the levels of the water in the beaker and the gas collection tube using a meter stick or ruler. Record this value.
11. Measure the temperature of the water in the beaker. Use this temperature as an approximation for the temperature of the gas
12. Discard the solution in the tube and the beaker and rinse all of your apparatus with tap water. Wash your hands thoroughly before leaving the lab.

Sample DATA Table

Barometric Pressure	769.4	Torr
Temperature of the hydrogen gas	23	°C
Mass of 1.00 meter of Mg Ribbon	1.05	grams
Length of Mg Ribbon used	11.43	millimeters
Measured Volume of Gas	34	cm ³
Difference in levels (h)	11.43	millimeters
Vapor Pressure of water at Temperature recorded	23.76	Torr

$$30.39 \text{ in Hg} \left(\frac{760 \text{ Torr}}{29.92 \text{ in Hg}} \right) = 769.4$$



$$\frac{0.129 \text{ Mg}}{11.43 \text{ cm}} \left(\frac{100 \text{ cm}}{1 \text{ in}} \right) = 1.05 \text{ g/in}$$

$$4.5 \text{ in} \left(\frac{2.54 \text{ cm}}{1 \text{ in}} \right) = 11.43 \text{ cm}$$

Format for the Calculations

1. To calculate the Adjusted Pressure of the gas:

$$P_{H_2} = P_{\text{Barometric}} - h - \text{Vapor Pressure of Water (for the temperature at which the gas was collected)}$$

$$13.6 - 23.76 - 0.05 = 0.79 \text{ Torr}$$

$$34 \text{ mL } H_2 \left(\frac{1 \text{ K}}{1000 \text{ mL}} \right) \left(\frac{\text{mol}}{22.4 \text{ L}} \right) = 0.0015 \text{ mol}$$

$$0.12 - 0.05 = 0.07$$

2. To convert the measured volume of H_2 to STP using the combined gas laws.

$$0.07 \text{ g Mg} \left(\frac{\text{mol}}{24.3 \text{ g}} \right) = 0.0028 \text{ mol}$$

$$V_{STP} = V_{\text{meas}} \times \frac{\text{Adjusted Pressure}}{760 \text{ torr}} \times \frac{273 \text{ K}}{\text{Temperature in Kelvin}}$$

$$\text{difference} = 0.0013 \text{ mol}$$

3. To calculate the mass of magnesium used

$$\text{Mass Mg} = \text{length (mm)} \times \frac{\text{mass of 1.00 meter Mg}}{1000 \text{ mm}}$$

4. To calculate moles of Mg used

$$\text{Moles} = \frac{\text{mass (g)}}{\text{molar mass (g/mol)}}$$



3

SL

Purpose:

To determine experimentally the molar volume of hydrogen gas by measuring the volume of hydrogen gas produced by a given mass of magnesium metal.

Hypothesis:

I predict that the molar volume of hydrogen will be the same as the molar volume of magnesium because there is a 1:1 mole ratio for magnesium and hydrogen.

Procedure:

1. Put on lab apron and goggles and gather materials.
2. Record the barometric pressure and the room temperature.
3. Get a piece of magnesium ribbon and record its mass. Also measure it to the nearest millimeter.
4. Obtain a piece of fine copper wire about 10 cm long. Roll the magnesium in a small ball and encase it in a cage of copper wire.
5. Add approximately 300 mL of water to the 600 mL beaker.
6. Carefully add 10 mL of 6 M hydrochloric acid to the gas collection tube. Incline the tube slightly and continue filling the tube with water from the 600 mL beaker. While pouring the water in the tube try to rinse down any acid that might have remained on the sides of the tube. Avoid agitating the bottom acid or the interface between the water and the acid if possible. Attach the magnesium package encased in copper wire at mouth of the gas collection tube.
7. Immediately invert the collection tube into the beaker containing the water. Allow the chemical reaction to continue until no more gas is generated. When the reaction has stopped, allow the apparatus to cool 3-5 minutes so that it is at room temperature.
8. Measure the volume of gas generated by using the displacement method with water and a graduated cylinder.
9. Clean up all materials.

Data:

Barometric Pressure	769.4 Torr
Temperature of the hydrogen gas	23°C
Mass of 1.0 meter of Mg Ribbon	1.05 grams
Length of Mg Ribbon used	114.3 millimeters
Measured Volume of Gas	34 mL
Moles of Mg	.0028
Moles of H ₂	.0015

Data Analysis:

We were given the barometric pressure and the temperature of the hydrogen gas. We measured the length of Mg ribbon to be 4.5 inches and multiplied by 2.54 to convert to centimeters and then multiplied that answer by 10 to convert to millimeters. We weighed the 114.3 millimeters of Mg ribbon and got .12 grams of Mg ribbon. In order to find the mass of 1.0 meter of Mg ribbon we had to divide the .12 grams by the 114.3 millimeters and then multiply by 1000 millimeters to end up with 1.05 grams per meter. To find the volume of the hydrogen gas we used the displacement method and came up with 34 mL or cm^3 . We also weighed the magnesium after the reaction and came up with .05 grams. We subtracted the .05 grams from the .12 grams and got an answer of .07 grams. We divided the .07 grams by 24.3 g to find that there were .0028 moles of magnesium. We divided the 34 mL by 1000 to convert to liters and then divided by 22.4 L, which is the standard volume to find that there were .0015 moles of hydrogen gas.

Evaluation:

There were some errors in the lab. There was a loss of acid when the test tube was flipped leaving a small amount of air to mix with the hydrogen gas. We also only used a 1M solution and the lab called for a 6M solution, so the reaction took longer and the magnesium never fully dissolved generating into the hydrogen gas. Also we had acid in the beaker instead of water so when the magnesium was being brought to the test tube it was being dissolved in the acid.

Percent Error- $(.0028-.0015)/.0028 * 100\% = 46.43\%$

Conclusion:

In conclusion our hypothesis was fairly correct considering all the errors in the lab. The errors prevented the mole values of the magnesium and the hydrogen gas from being exactly the same.

	Pl(a)	Pl(b)	DC	DPP	CE
Me	n c	n c	1	1	0
Teacher					
Moderator	2	2	0	1	1

(T)

SL

Instructions given to the students:

Investigate the factors affecting the rate of reaction. Plan an experiment to show the effect of each of the factors.

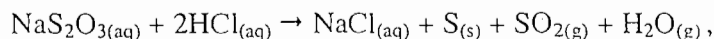
The rate of reaction

Aim: To investigate the factors affecting the rate of reaction.

Different factors that affect the rate of reaction:

1. Temperature:

Hypothesis: The rate of reaction will increase with increasing temperature. When the temperature of the solution is increased the molecules gain kinetic energy and therefore will move faster. This means that there will be more collisions and also the amount of energetic collisions (collisions with enough energy for a reaction to take place) will increase. An example of a reaction where this can be seen is:



which will also be used in the experimental part of the experiment. The rate of reaction will be determined by the time it takes for the reaction to form a white precipitate of sulfur.

Considering the theorem of the Maxwell-Boltzman distribution it can be assumed that the rate of reaction increases a lot even for small increases in temperature. (i.e. the precipitate of sulfur will form in half the time for an increase in temperature of only a few °C).

Depends on the order of the reaction! The correlation can be linear or exponential.

Variables: Independent: Temperature ✓
 Dependent: The rate of reaction ✓ *time taken for the cross to disappear*
 Controlled: Concentration of the solution -
 Surface area of the reactants (i.e. lumps or powder)
 Catalyst usage ✓
 Conditions of the environment (pressure, temperature etc.)

Apparatus:

- Beakers
- Bunsen burners
- Tiles
- Tripods
- Aqueous sodium thiosulfate
- Hydrochloric acid
- Stopwatch



Method:

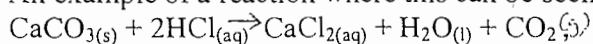
1. Measure 50ml of both hydrochloric acid and sodium thiosulfate
2. Pour the two solution together
3. Measure the time it takes for a white precipitate of sulfur to form (i.e. when a black cross on the bottom of the beaker cannot be seen anymore.)
4. Measure 50ml of both hydrochloric acid and sodium thiosulfate and heat them until their temperatures both have increased by 10°C.
5. Repeat steps 2 and 3
6. Measure 50ml of both hydrochloric acid and sodium thiosulfate and heat them until their temperatures both have increased by 20°C.
7. Repeat steps 2 and 3

2. Concentration of the solution:

Hypothesis: The rate of reaction will increase with increasing concentration of the solution. Increased concentration means that there are more particles for the same volume of solution. This means that there will be more collisions amongst the particles and the amount of particles with enough energy for a reaction to take place colliding increases.



An example of a reaction where this can be seen is:



In this reaction a lot of gas is given off, in order to investigate the rate of reaction the amount of gas given off will be recorded against a certain amount of time.

Variables:

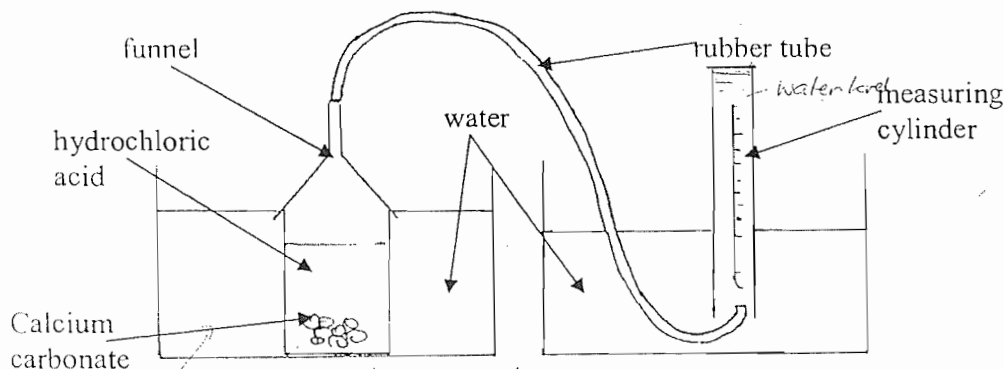
- Independent:** Concentration of the solution *HCl*, mass of *CaCO₃*
- Dependent:** The rate of reaction
- Controlled:** Temperature
Surface area of the reactants (i.e. lumps or powder)
Catalyst usage
Conditions of the environment (pressure, temperature etc.)

Apparatus:

- Beakers
- Calcium Carbonate (chips)
- 0.25M, 1.0M, 2.0M hydrochloric acid
- stopwatch
- gas collection set (funnel, measuring cylinders, rubber tubes etc.)

Method:

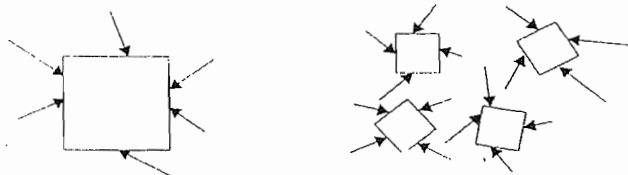
1. Set up the apparatus ready for gas collection
2. Record the times for the reactions to give off certain amounts of gas (i.e. 10, 20, 30, 40 cm³), compare the biggest common values.
3. Repeat the experiment for the different concentrations of hydrochloric acid.



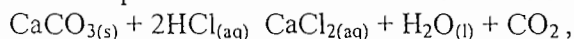
Would you prefer using funnel instead of stopper?
Why water? To control the temperature?

3. Surface area of the reactants:

Hypothesis: This factor relates to the solid reactants in the reaction. With increasing surface area the rate of reaction will increase. The greater the surface area, the more particles are 'exposed' to collisions. More often particles with enough energy for a reaction to take place will collide. The amount of energetic collisions will increase.



An example of a reaction where this can be seen is:



In this reaction a lot of gas is given off, in order to investigate the rate of reaction the amount of gas given off, by both chips and powder of CaCO_3 , will be recorded against a certain amount of time. It is assumed that the same amount of gas is given off by both the powder and the marble chips (for the same masses), but in less time for the powder.

Variables:

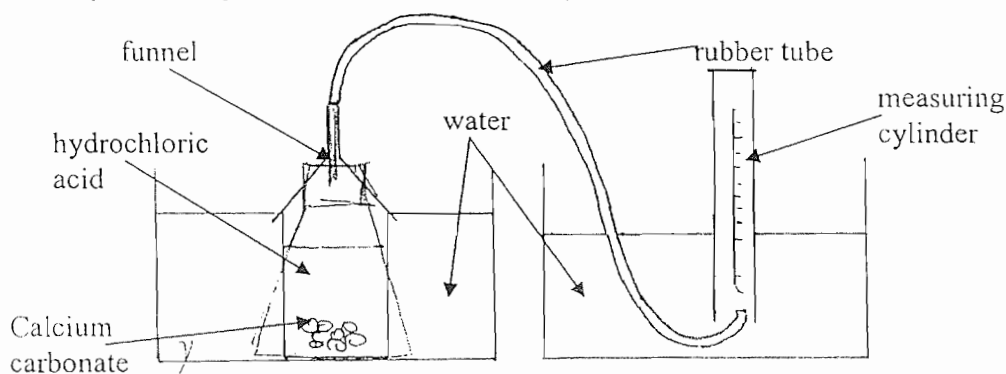
- Independent:** Surface area of the reactants (i.e. lumps or powder)
- Dependent:** The rate of reaction
- Controlled:** Temperature
- Concentration of the solution
- Catalyst usage ²
- Conditions of the environment (pressure, temperature etc.)
- mass of CaCO_3

Apparatus:

- Beakers
- Calcium Carbonate (chips and powder)
- Hydrochloric acid
- stopwatch
- gas collection set (funnel, measuring cylinders, rubber tubes etc.)

Method:

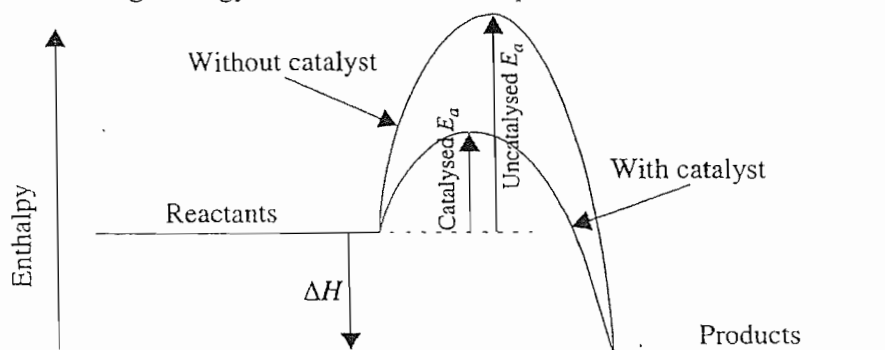
1. Set up the apparatus ready for gas collection
2. Record the times for the reactions to give off certain amounts of gas (i.e. 10, 20, 30, 40 cm^3), compare the biggest common values.
3. Repeat the experiment for the different types of Calcium Carbonate. ✓



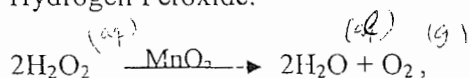
To control the temperature?

4. Catalysts:

Hypothesis: Using a catalyst in a reaction will increase the rate of reaction. A catalyst is a substance that increases the rate of chemical reaction without undergoing any overall change. Catalysts achieve this by providing an alternative reaction mechanism with a lower activation energy by which the reaction can take place, so that a greater proportion of collisions will have enough energy for a reaction to take place.



An example of a reaction where this can be seen is the decomposition of Hydrogen Peroxide:



Without the manganese oxide catalyst the reaction is so slow that it is not easily visible/observed, but with the catalyst it is very rapid.

Variables:

- Independent:** Catalyst usage / The mass of catalyst used
- Dependent:** The rate of reaction
- Controlled:**
 - Temperature
 - Concentration of the solution H_2O_2
 - Surface-area-of-the-reactants (i.e. lumps or powder) — No solid substances!
 - Conditions of the environment (pressure, temperature etc.)

Apparatus:

- Beakers
- Aqueous Hydrogen Peroxide
- Manganese oxide
- Goggles

Method:

1. Put the Hydrogen Peroxide into a beaker and observe any changes for appr. 5-10 mins
2. Put the same amount of Hydrogen Peroxide into a second beaker and add the Manganese oxide. Observe any changes for appr. 5 mins, for safety wear the goggles (the reaction should be fairly vigorous).

Data Collection:

Due to lack of time only one of the factors was investigated (temperature).

$\pm 0.5^\circ\text{C}$

Temperature / $^\circ\text{C}$	Time / sec
21.5	59
30.0	32
40.0	18
50.0	11

See graph.

Conclusion and Evaluation:

The graph clearly shows that the rate of reaction, or the time needed for the precipitate to be formed, is much faster at higher temperatures. When looking at the values of 21.5°C (not 20°C because the water would have had to be cooled below room temperature) and 30°C , it is possible to state the hypothesis for this experiment was proved; for an increase of less than 10°C the time needed for the precipitate to be formed was nearly halved. *V. good Quantitative*

The experiment does not necessarily require any improvements as it was only designed to show the relation of the temperature against the time needed for the precipitate to be formed, say, the relation between the temperature and the rate of reaction. Nevertheless more accurate values could have been obtained by controlling the temperature more strictly, such as keeping the whole system isolated from the environment to prevent any heat or energy interchanges. Additionally 'light gates' could have been used to determine when the precipitate had formed instead of the observer telling by naked eye.

colorimeter

light sensor



	P1(a)	P1(b)	CE
Me	2	2	✓
Teacher			
Moderator			

25. **Experiment Title:** Which is the most efficient fuel; ethanol, propanol or butanol?

Introduction

- Alcohols can be used as fuels to heat water. This investigation compares the mass of fuel used to the temperature rise of the water to determine which fuel is the most efficient.
- The three fuels tested will be the alcohols ethanol, propanol and butanol.

Method

1. Determine the mass of one of the spirit burners containing an alcohol on an electronic balance.
2. Set up a copper beaker about 5-10 cm above the spirit burner on a heat-proof mat.
3. Measure 50 cm³ of water into the beaker using a measuring cylinder.
4. Take the temperature of the water using a thermometer.
5. Light the alcohol in the spirit burner and allow it to heat the water in the beaker for 2 or 3 minutes.
6. Extinguish the flame and then take the maximum temperature of the water in the beaker.
7. Determine the mass of the spirit burner after the experiment on a balance.
8. Repeat the experiment with fresh water and a different alcohol.
9. Repeat the experiment for each alcohol.
10. Record all your raw data and observations.
11. Use these to determine which of the alcohol fuels is the most efficient.
12. Find the literature values for the enthalpy of combustion of these fuels and then give a valid conclusion and an evaluation of this experiment.

Assessment Criteria.

You may be assessed on your Data Collection, Data Processing, and Conclusion/Evaluation skills.

IB Chemistry Internal Assessment - Energetics

Planning A

Research Question ~>

How does the volume of water affect the temperature change of water during the combustion of ethanol?

Variables ~>

Independent: The volume of water is the variable which will be changed and so in each test, a different volume will be used.

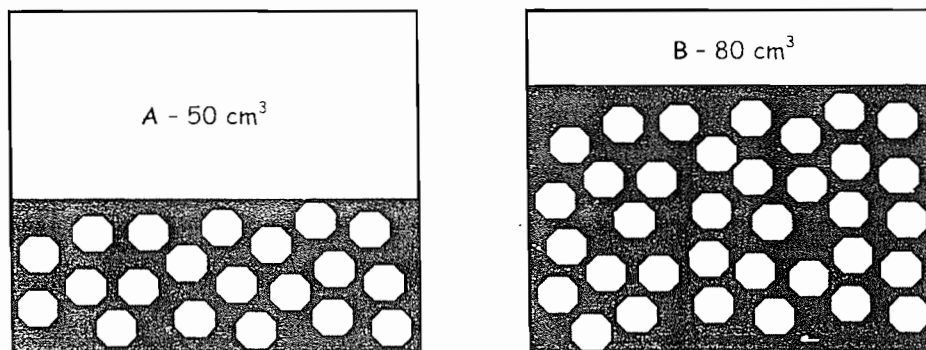
Dependant: The temperature change of water is the variable which will be measured.

Control: The following variables will be kept the constant to maintain fairness.

- The volume of ethanol used.
- The spirit burner used. (the surface area and type of burner will be the same)
- The beaker containing the water (the surface area of the beaker will be the same)
- The height of the beaker above the spirit burner.
- The time allowed for combustion to take place.
- The temperature of water at the start of each test.
- Surrounding (room) temperature

Hypothesis ~>

My hypothesis is that as the volume of water increases, the temperature change will decrease. This can be explained with the help of the diagrams drawn below.



If the control variables were kept the same, then beaker A will have a higher change in temperature. As it can be seen, in beaker A where there is 50 cm³ of water, there are fewer water particles when compared to beaker B. The temperature increases when water is heated. However, when it reaches the boiling point, water maintains at the same temperature (100°C) until the boiling process has finished. (When all the bonds have been broken) This also means that if there are more particles in a beaker being heated, it will take a longer time for it to boil. Hence, when the same amount of energy is being transferred to both beakers, (I.e. when the same volume of ethanol used for the combustion), more time is required for this energy to reach all the numerous particles in beaker B. As a result, beaker A will heat up faster and therefore have a greater change in temperature.

$\Delta H = mc \Delta T$ should be used to explain.

Page 1

Also $\Delta H =$ enthalpy of combustion.

Planning B

Apparatus and Materials ~>

I plan to use the following apparatus and materials for this investigation.

- A 100°C thermometer
- A 500 cm³ beaker
- 50 cm³ of Ethanol
- Tap Water (temperature should be the same from the taps but the volumes will change as listed below)
- 200 cm³ measuring cylinder (for measuring the volume of water)
- 50 cm³ measuring cylinder (for measuring the volume of ethanol)
- A pipette
- 2 clamps to hold the thermometer and beaker in place
- Clamp holder
- A spirit burner
- Heatproof mat
- Stopwatch
- Matches

good

Method ~>

I intend to follow this procedure for each test:

- Accurately measure out 50 cm³ of ethanol using the 50 cm³ measuring cylinder and later a pipette for the final drops, and pour this into the spirit burner.
- Accurately measure out the volume of water ^(from the bottom of the meniscus) using the 200 cm³ measuring cylinder and pour this into a 500 cm³ beaker. The volumes which I will use are 100 cm³, 150 cm³, 200 cm³, 250 cm³ and 300 cm³.
- On the heatproof mat, place the clamp holder with the clamps securely tightened. The higher clamp should hold the thermometer in place and the other one should hold the beaker of water in place.
- Position the spirit burner directly below the beaker of water. It is important that the distance between the base of the beaker of water and the top of the spirit burner is the same in every test to keep it fair.
- Note down the temperature of the water.
- Using a match, light the spirit burner and start the stopwatch. Allow combustion to take place for 3 minutes. The time allowed for each test is another control variable which is vital to keep the test fair.
- After 3 minutes, note down the temperature of water reached and calculate the temperature change.
- Repeat experiment for all volumes of water. The same size beakers and spirit burners should be used to ensure the surface area of the containers don't change. This is to ensure fairness.

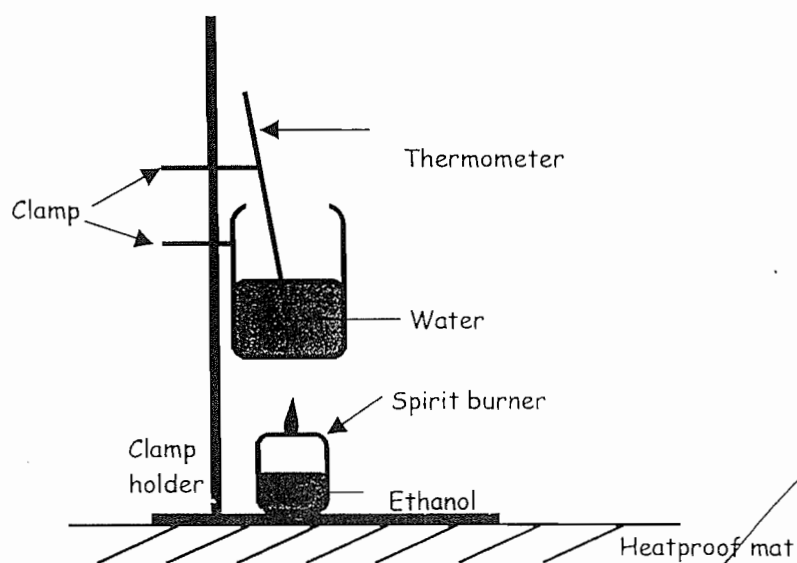
good

- Fair test =

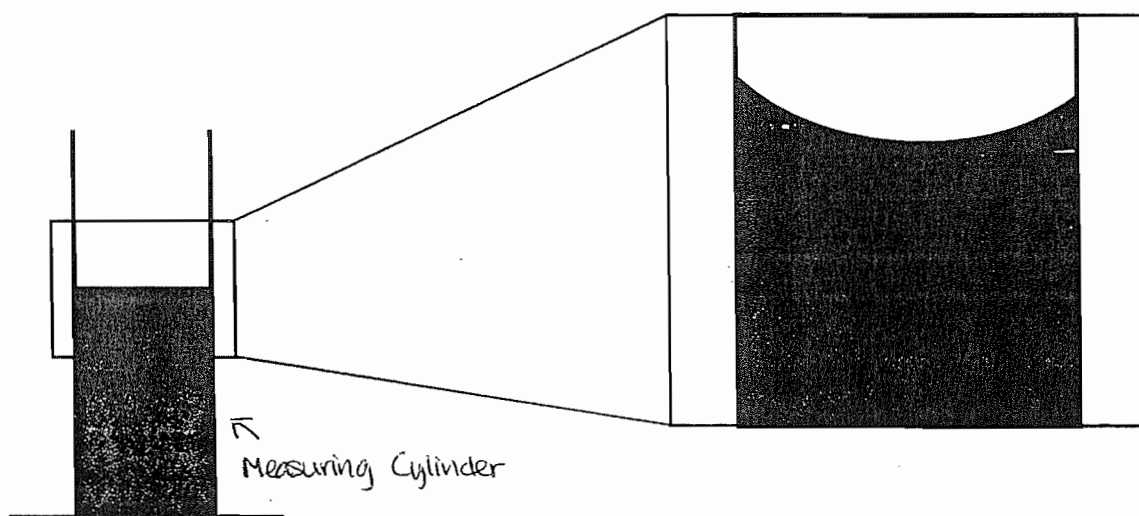
- Data collected =

} make this v. clear & specific.

The diagram below illustrates the apparatus for the experiment:



When measuring the volume of water and ethanol using the measuring cylinders, the measurement should be taken from the meniscus (the lowest point).



Data processing (i.e. your raw data)

5

Data Collection

The recorded results from my investigation and the uncertainties are in the table below:

Independent	Control	Dependent				
Volume (cm ³)	Start Temp. (°C)	End Temp. 1 (°C)	Δ Temp. 1 (°C)	End Temp. 2 (°C)	Δ Temp. 2 (°C)	Average Δ Temp. (°C)
50 '1	24 '1 (room temp.)	78 '1	54 '2	91 '1	67 '2	60.5 '2
100 '2		79 '1	55 '2	71 '1	47 '2	51 '2
150 '3		57 '1	33 '2	55 '1	61 '2	32 '2
200 '4		49 '1	25 '2	49 '1	25 '2	25 '2
250 '5		78 '1	24 '2	44 '1	20 '2	22 '2

Observations And Other Important Data ~>

- The fan was on when I was testing the 50 cm³ of water for the first time. The flame flickered in all directions rather than mainly at the beaker.
- During all the testing for the first set of results, at least 1 cm of the wick was soaked in the ethanol. In the second set of results, only the tip of the wick was touching.
- The distance between the tip of the wick and the bottom of the beaker was 4 cm each time.

Changes From The Plan ~>

Time taken for heating = ?

Type of beaker = ?

- I used a 100 cm³ measuring cylinder instead of a 200 cm³ measuring cylinder because there were none available for me to use.
- I had to change the 500 cm³ beaker to a 200 cm³ beaker because the large beaker wouldn't fit in the clamp. This meant I also had to adjust the values for my independent variables. I had decided to test 100 cm³, 150 cm³, 200 cm³, 250 cm³ and 300 cm³, but this changed to 50 cm³, 100 cm³, 150 cm³, 200 cm³ and 250 cm³.
- I did not realise this was an issue when I was writing up my plan. Since I used the same beaker each time, the beaker would already be heated up from the hot water from the previous test. Hence I washed the beaker after each time and dried it before using it for the next test to keep the surrounding temperature constant and the volume of water as exact as possible.

Uncertainties = ? ± 1 cm³ etc.

→ These are not clear!

Data Processing

In the table below are my overall results from the practical. The results in depth are in my Data Collection.

Independent	Dependent
Volume (cm ³)	Average Δ Temp. (°C)
50 '1	60.5 '2
100 '2	51 '2
150 '3	32 '2
200 '4	25 '2
250 '5	22 '2

The results and the uncertainties were used to draw a graph, as shown on the page behind. There is a negative correlation between the relationship of the volume of water and its temperature change.

The intersection of each point display the averaged results. The lines extended from the points show the uncertainty for that value. A best fit line has also been drawn and two values, 100 cm³ and 200 cm³ have been taken to illustrate how the temperature change is expected to increase when the volume of water changes. According to my graph, the temperature should reach 46 °C when at 100 cm³ and 26 °C when at 200 cm³. The expected result for 200 cm³ is 52 °C (as marked with a green arrow on the graph) because if the volume of water is doubled, the temperature change is also expected to double. This theory is derived from the enthalpy equation:

$$\Delta H = mc\Delta T$$

The enthalpy (H) stays constant because only one fuel (ethanol) was used. The specific heat capacity (c) also stays the same because water is used throughout the experiment. Only the volume of water (m) changed, as it was my independent variable. This means my dependent variable, the temperature change must change in proportion in order for the equation to remain balanced.

Below I have used the values 100 cm³ and 200 cm³ to illustrate my point:


If $m = 100 \text{ cm}^3 \rightarrow 200 \text{ cm}^3 = 2m$

$$\Delta H = mc\Delta T \rightarrow \Delta H = 2mc(\Delta T/2)$$

Need to calculate ΔH for each volume

perhaps plot a graph of ΔH v's volume

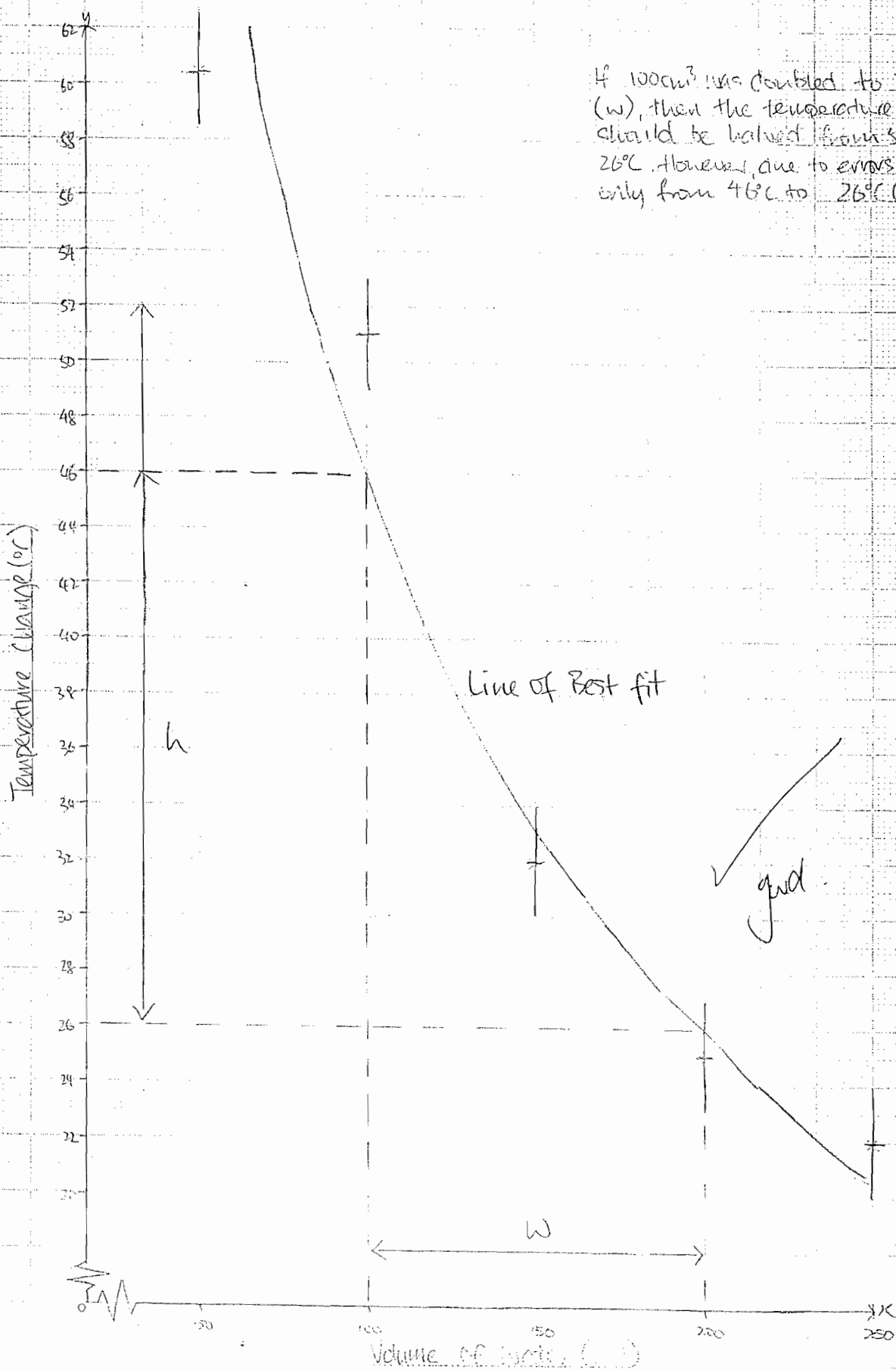
ΔH should be constant ΔH



explain why it is not.

42

Title: Relationship of The volume of water and its temperature change



$$n = 2.065 \times 10^{-5} \text{ mol}$$

$2.065 \times 10^{-5} \times 5 = 1.0325 \times 10^{-4} \text{ mol}$
in order to satisfy the 1:5 ratio, we multiply by 5.

$$n = \frac{m}{M}$$

Therefore $nM = m$

$$1.0325 \times 10^{-4} \times 56 = 5.782 \times 10^{-3} \text{ g}$$

Multiply by 1000 to get the units into milligrams, in future calculations, the cm^3 to dm^3 conversions will be omitted because dividing by 1000 and then multiplying by 1000 to get mg cancels each other out.

$$5.782 \times 10^{-3} \times 1000 = 5.782 \text{ mg}$$

The tablet was dissolved into a solution of 250 cm^3 each titration experiment requires about 25 cm^3 or $1/10^{\text{th}}$ of the tablet (assuming equal dispersion) so in order to calculate the mass for the entire tablet, and not just $1/10^{\text{th}}$ of it, we multiply 5.782 by 10.

$$5.782 \times 10 = \mathbf{57.82 \text{ mg}}$$

With errors

$$\text{Burette} = \pm 0.05 \text{ cm}^3 = 0.1\%$$

$$\text{Pipette} = \pm 0.05 \text{ cm}^3 = 0.2\%$$

$$\text{Volumetric flask} = \pm 0.6 \text{ cm}^3 = 0.24\%$$

$$\text{Total} = 0.54\%$$

$$\text{Mass of iron} = \mathbf{57.82 \text{ mg} \pm 0.54\%}$$

use appropriate sig. figs

i.e. $57 \pm 1\% \text{ mg}$

Conclusion

The reducing agent in the reaction is the H_2SO_4 , where it helps to take away the K^+ ions. Likewise, KMnO_4 is the oxidizing agent in this reaction.

The literary value for the mass of iron in 1 tablet is 60mg. However, the value I arrived to after having conducted several titrations tells me that the actual mass of the iron is in fact less than 60mg. The actual value, rounded to the nearest whole number is around 58mg. Which is close to the value given to it's consumers by the labs. However, it is most probable that the difference is caused by parts of the tablet that were stuck in the inside of the mortar, and due to incomplete reaction between the tablet and the sulfuric acid used.

Evaluation

The equipment was, on a whole fairly accurate. However, due to time limitations, sometimes the values were not as accurately recorded as they can be, the space for human error is very big, this includes recording results, and measuring out volumes of liquids.

The point where colour begins to change is the point where addition of the titrant stops. The colour change is normally fairly difficult to determine and once this point is reached, it is normal that an excess of titrant will be added. Thus different results will be had every time.

There were still bits stuck on the inside of the mortar, and residue left from undissolved parts of the tablet. This is probably one reason why the results are only a bit off from the given value.

In order to minimize human errors, it may be possible to use electronic equipment to measure accurately; the volume of the liquids, fewer mistakes will be made reading from an electronic display than reading from the actual apparatus.

The quickest solution to this problem would be to place the beaker of the substance onto a sheet of clean white paper, this way, the colour change will be more apparent. So the addition of titrant may be stopped as soon as possible.

To minimize loss, a mortar or something with a smooth crushing-surface would minimize the amount of the tablet that got lodged within the cracks. The ones used still had a fairly rough surface, which enabled the crushed powder to find their way into crevices. Also, due to time limitations, the powder did not fully dissolve a solution to this maybe to speed up the process by heating the solution.

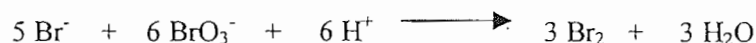
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Teacher		
Mentor		

heat + use more acid.

32. Determination of the Activation Energy for the Reaction between Bromide and Bromate (V) Ions

Introduction

The aim of this experiment is determine the activation energy (E_A) for the reaction between bromide (Br^-) and bromate (BrO_3^-) ions.



The rate of this reaction can be followed by determining how quickly the bromine produced reacts with some phenol that has been added. When all the phenol has been consumed any bromine produced will bleach an indicator such as methyl red immediately.

Since the rate constant (k) for this reaction will be proportional to the time taken (t) for the methyl red to be bleached, this can be substituted into the Arrhenius equation as follows.

$$\text{Arrhenius equation: } k = A e^{-E/RT}$$

$$\text{Substituted equation: } c/t = A e^{-E/RT}$$

Where c is a constant for this reaction, A is the Arrhenius constant for the collision orientation, R is the gas constant and T is the temperature.

$$\text{Taking the natural log of this: } \ln t = \ln c - \ln A + E_A / RT$$

So that a graph of $\ln t$ against $1/T$ will have a gradient that can be used to determine the activation energy for the reaction.

IB Chemistry Internal Assessment - Kinetics Using Arrhenius Equation

Data Collection ~>

Observations:

Once the temperature of the mixture had reached the temperature indicated on the instructions, I mixed the acid with the mixture and started the stopwatch. However, during this process, the solutions continue to cool down so the temperature isn't accurate. Also, before I finished pouring all the acid from one test tube to another, the acid had already started reacting with the mixture but I didn't start the stopwatch till after all the acid was in the other test tube. This means the actual time of the reaction is slightly more than recorded since I was a little late at starting the timing.

good

Table of Results:

Temperature (K) ± 2	Time Taken (sec) ± 2
343	5.41
337	8.66
327	14.06
320	26.84
309	37.28
299	171.77
286	354.55

but you must record the colour change... this is a v. important observation.

Other Important Data:

- There was four drops of methyl red indicator in each conducted experiment.
- Phenol used $\sim 10\text{cm}^3$ of 0.01 mol dm^{-3} .
- Bromide/Bromate mixture used $\sim 10\text{cm}^3$.
- Sulfuric Acid used $\sim 5\text{cm}^3$ of 0.5 mol dm^{-3} .

} uncertainty = $\pm 0.5\text{cm}^3$ (not as important but worth recording)

Quantitative Uncertainties:

There are many uncertainties which can be calculated from this experiment, but the main factors which will affect the results are time (± 2) and temperature (± 2).

	DPP
Me	
Teacher	
Moderator	

Data Processing ~>

Temperature (°C) ± 2	Temperature (K) ± 2	Temperature (1/K)	Time Taken (min' sec") ± 2 sec	Time Taken (sec) ± 2	Ln t
70	343	2.92×10^{-3}	5"41	5.41	1.69
64	337	2.97×10^{-3}	8"66	8.66	2.16
54	327	3.06×10^{-3}	14"06	14.06	2.64
47	320	3.13×10^{-3}	26"84	26.84	3.29
36	309	3.24×10^{-3}	37"28	37.28	3.62
26	299	3.34×10^{-3}	2'51"77	171.77	5.15
13	286	3.50×10^{-3}	6'04"55	364.55	5.99

NoTe

- To change the temperature from degrees Celsius into Kelvin, I added 273K to the degrees value.
- For all the Ln values, I used the logarithmic function on the results the "Time Taken (sec)".

I have used the values of the temperature (1/K) and the values of Ln t to produce the graph on the next page. Using the gradient of the graph and the logarithmic form of the Arrhenius equation, I can calculate the activation energy. Since the graph is a straight line with a constant gradient, I can make connections with a simple formula $y = mx + c$ and the logarithmic form of the Arrhenius equation:

$$\begin{array}{rcl} y & = & c + m x \\ \text{Ln } t & = & (\text{Ln } c - \text{Ln } A) + \frac{E_a}{R} \frac{1}{T} \end{array}$$

I can ignore the y-intercept c (the $\text{Ln } c - \text{Ln } A$) as it isn't important and it doesn't affect my calculations. I have plotted the graph where Ln t is on my y-axis and temperature (1/K) is on my x-axis, as represented above. This means the gradient (m) on the graph is represented by the E_a/R . R is the gas constant and its value is 8.314. The gradient is calculated from the best fit line drawn on the graph. Hence I can calculate the activation energy by multiplying the gas constant with the gradient.

well explained

NoTe All values used in the calculations are figures from my red graph on the next page.

$$\begin{array}{rcl} \text{Gradient (m)} & = & \Delta y / \Delta x \\ m & = & 4 / 5.5 \times 10^{-4} \\ m & = & 7272 \text{ (nearest whole number)} \end{array}$$

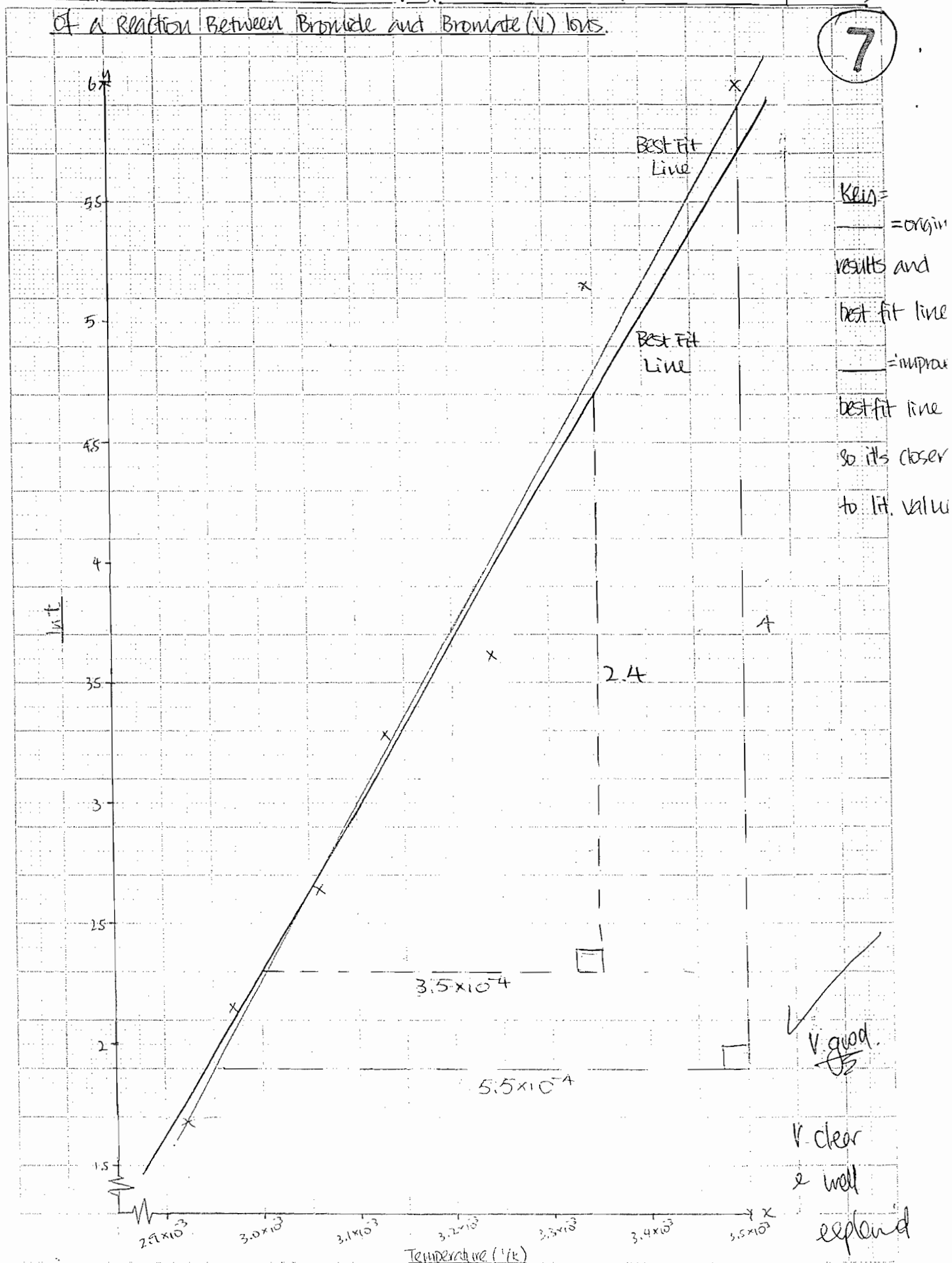
$$\begin{array}{rcl} E_a & = & R * m \\ E_a & = & 8.314 * 7272 \\ E_a & = & 60465 \text{ J mol}^{-1} \text{ (nearest whole number)} \\ E_a & = & 60 \text{ KJ mol}^{-1} \text{ (nearest whole number)} \end{array}$$

The activation energy according to my gradient is 60 KJ mol^{-1} . However, this figure isn't very accurate because the values I used to calculate it were from the gradient I drew from the best fit line. This means, the activation energy will be different depending on how steep or flat I drew the best fit line to be. These are some of the limitations of an accurate result that occur with the uncertainties obtained from the experiment specifically with temperature and time.

11th: Graph showing the relationship of $\ln t$ and $1/K$ (time and temperature)

of a reaction between Bromide and Bromate(V) ions.

7



The best fit line drawn on the graph is a straight line with a positive correlation. The straight line is due to the proportionate increase and therefore giving a constant gradient as mentioned already. As the temperature increases, the time taken for a reaction decreases. This generally gives a negative relationship. However, in my graph, I used $1/K$ and not simply K , so with a smaller value of $1/K$, it means it's at a higher temperature. This then explains the increasing straight line between $\ln t$ and $1/K$.

Conclusion and Evaluation ~>

The activation energy is the minimum energy required for there to be a collision between reactants, ie for a reaction to occur.

The literature value given is 54 kJ mol^{-1} . The value I calculated from the gradient was 60 kJ mol^{-1} (to the nearest whole number). My value is higher than the literature value. This means my best fit line is steeper than it is meant to be, which brings back to the point made earlier about the accuracy of the results depend on the line I drew on my graph. If I drew the best fit line (the blue graph) slightly flatter, it would give a different value:

$$\begin{aligned} \text{Gradient (m)} &= \Delta y / \Delta x \\ m &= 2.4 / 3.5 \times 10^{-4} \\ m &= 6857 \text{ (nearest whole number)} \end{aligned}$$

$$\begin{aligned} E_a &= R * m \\ E_a &= 8.314 * 6857 \\ E_a &= 57010 \text{ J mol}^{-1} \text{ (nearest whole number)} \\ E_a &= 57 \text{ kJ mol}^{-1} \text{ (nearest whole number)} \end{aligned}$$

But you need to explain

what E_a is in your

conclusion... also why it

stays constant.

As it can be seen, if I drew the gradient differently, it would give me a different value and in this case, the blue line graph is flatter and so the value is closer to the literature value. If I drew the gradient slightly more flat, the value would be even closer to the literature value. excellent!

There are many errors in this particular experiment. Both the time and the temperature are used to draw the graph. This means the precision of the results depend largely on the accuracy of the times and temperatures I collected. Since I started and stopped the time whenever I felt was the start and the end of the reaction, the timing could have been out by seconds. It was also difficult to tell accurately when the reaction finished because the faint pink indicating the reaction hasn't finished, was sometimes hard to distinguish from a clear solution. Similarly with the temperature taken. I read it off the thermometer to the nearest degree, so this wasn't accurate. The main inaccuracy with temperature was that I took the value from the starting temperature. However, during the reaction, the temperature continued to drop gradually as it cooled over time.

→ Volumes are also v. important!

If I were to do this experiment again, I would use a colour spectrometer and it would more accurately detect the change in colours and so the timing would be more perfect. With the temperature error, instead of heating the recants and then once it has reached the proposed temperature, stop the heating, I would opt for the use of a water bath. By doing so, the temperature would be most constant and therefore more correct. The most obvious perfection is to repeat the experiment. This gives a greater range of results and minimises the chance of anomalies. If these improvements were untaken, the results would be much better and closer to the literature results because these values are used to draw the graph to calculate the activation energy.

Excellent effort

52

1 credit.

Determining the enthalpy change of a reaction

Instructions to student

AIM: To determine the enthalpy change for the following displacement reaction.

METHOD

- 1) Prepare 1.00M CuSO_4 (aq)
- 2) Pipette 25ml of the copper sulphate solution into a calorimeter.
- 3) Weigh about 6g of zinc powder. Zn is used in excess so there is no need to be very accurate.
- 4) Record every half minute for $2\frac{1}{2}$ minutes the temperature of CuSO_4 solution.
- 5) Add zinc at precisely 3 minutes. (Stir!)
- 6) Record the temperature for additional 6 minutes.

DATA COLLECTION

Collect your data representing it clearly and in organised manner. Record the inaccuracies appropriately.

DATA ANALYSIS

Draw a graph temperature vs. time. Label your axes and mark the inaccuracies your graph.

Extrapolate the curve to 3 minutes to establish the maximum temperature rise.

Calculate the enthalpy change for the reaction (Give your answer for one mole) and make sure that your exp. Write up contains the thermochemical equation of the reaction.

EVALUATION

Accepted value for the reaction: -217kJ/mol . Calculate your percentage error.

ASSESSMENT

Data collection, data analysis and evaluation will be assessed.

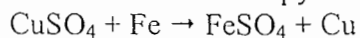
NOTES:

[REDACTED]

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He.		
Teacher		
Moderator		

Determining the enthalpy change of a reaction

Aim: to determine the enthalpy change for the displacement reaction



State signs must be recorded in all thermometric equations.

(Hypothesis: Since the reaction between iron and copper sulphate is very violent, there will be a big change in temperature of the mixture. Therefore it can be assumed that there will be a big enthalpy change for the reaction. ✓

Method:

- 1M copper sulphate solution was prepared.
- 25ml of the solution was pipetted into a calorimeter
- 6g of iron powder was weighed
- the temperature of the copper sulphate solution was measured and recorded for 2.5 minutes.
- 3 minutes after starting the measurements the iron powder was added into the calorimeter
- under constant stirring of the solution the temperature of the solution was measured and recorded for further 6 minutes. ✓

(Apparatus:)

- Pipette
- Calorimeter
- Electr. Balance
- Stopwatch
- Digital thermometer
- Copper sulphate solution
- Iron powder
- Distilled water

Variables: Dependant: temperature
These are needed only in planning! Controlled: pressure ✓

concentration of the copper sulphate solution — Better amount of mass of iron powder (since it was used in excess) independent CuSO_4 ✓

Data collection:

	Temperature ($^{\circ}\text{C} \pm 0.3$)
Time (seconds)	23.1
15	23.1
30	23.1
45	23.1
60	23.1
75	23.1
90	23.0
105	23.0
120	23.0
135	23.0
150	23.0
165	23.0
180	23.0
195	27.2
210	27.9
225	28.3
240	30.0
255	29.8
270	31.1
285	33.8
300	35.9
315	37.3
330	38.1
345	39.6
360	41.3
375	42.1
390	43.1
405	44.5
420	44.7
435	45.1
450	45.4
465	46.0
480	46.2
495	46.0
510	45.9
525	45.7
540	45.6

Temp._{min}: 23.0

Temp._{max}: 49.6 (by extrapolating the graph to 3 minutes)

$$s_{(\text{H}_2\text{O})} = 4.18 \text{ JK}^{-1}\text{g}^{-1}$$

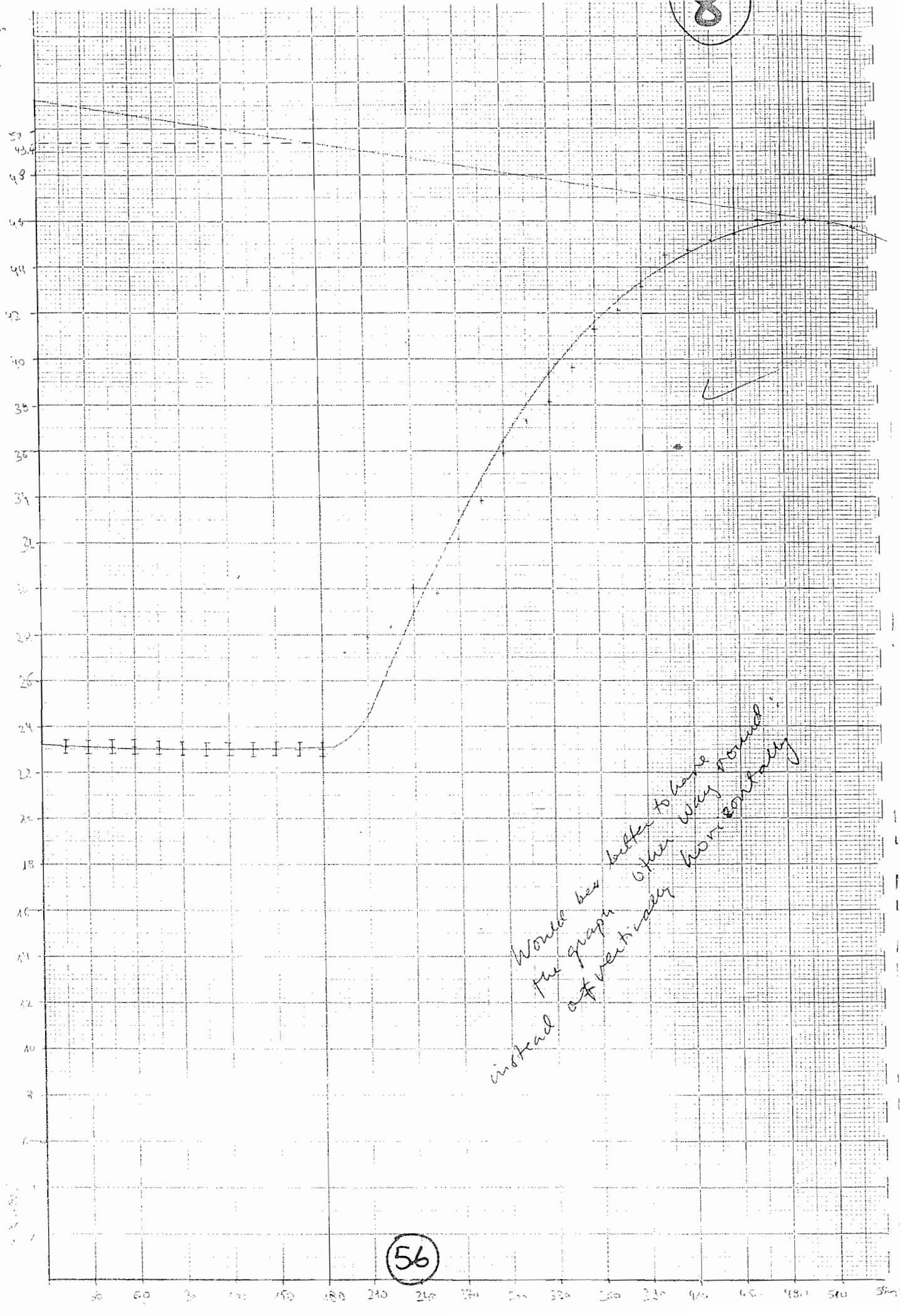
$$m_{(\text{H}_2\text{O})} = 25 \text{ g} \pm 0.005\text{g}$$

$$\Delta T = (49.4^{\circ}\text{C} - 23.0^{\circ}\text{C}) \pm 0.6^{\circ}\text{C} = 26.4^{\circ}\text{C} \pm 0.6^{\circ}\text{C} = 26.4 \text{ K} \pm 0.6 \text{ K}$$

$$c_{(\text{CuSO}_4)} = 1 \text{ mol.l}^{-1}$$

$$V_{(\text{CuSO}_4)} = 25 \text{ ml} \pm 0.1 \text{ ml} = 0.025 \text{ l} \pm 0.0001 \text{ l}$$

8



56

Data analysis:

From $s_{(H_2O)}$, $m_{(H_2O)}$ and ΔT the amount of heat given out during the reaction can be calculated, since $\Delta Q = sm \Delta T$:

$$\Delta Q = s_{(H_2O)} \cdot m_{(H_2O)} \cdot \Delta T$$

$$\Delta Q = 4.18 \text{ J/Kg} \cdot 25 \text{ g} \cdot 26.4 \text{ K} = \underline{2758.8 \text{ J}} \pm ?$$

In order to find the enthalpy of the reaction, per 1 mole, the heat given must be divided by the number of moles present in the reaction:

Therefore: $\Delta H = \Delta Q / n$, where $n = c_{(CuSO_4)} \cdot V_{(CuSO_4)}$

Therefore:

$$\begin{aligned} \Delta H &= \Delta Q / (c_{(CuSO_4)} \cdot V_{(CuSO_4)}) \\ &= 2758.8 \text{ J} / (1 \text{ mol/l} \cdot 0.025 \text{ l}) \\ &= 110352 \text{ J/mol} \\ &= \underline{110.35 \text{ kJ/mol}} \pm \end{aligned}$$

That's for $W_{50m(laq)} + 2m(s)$!

Conclusion and Evaluation:

The accepted value for the reaction is 217 kJ/mol. This means a percentage error of 51%. ✗

Not enough to explain

This vast error in the result can be explained by the fact that no perfect isolation for the calorimeter from the environment can be provided. Therefore immense heat (energy) loss to the environment falsified the results of the experiment. ✗

In order to improve the experiment better insulation of the calorimeter from the environment should be used. Furthermore the solution could be less concentrated in order to make the reaction less vigorous and therefore have less heat loss to the environment, meaning more exact results. If possible a magnetic stirrer could have been used in order to make the reaction happen more steadily and equally over the time interval. Even though the time interval was relatively short, giving relatively precise results, a computerized recording of the temperature change could have been used.

$$D_c = c_c = 3$$

$$D_{pp} = c_p = 2$$

Teacher Instructions

(4)

HL

Solubility of $X(OH)_2$

Aim

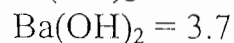
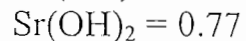
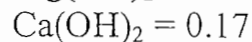
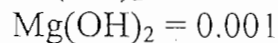
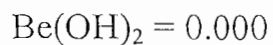
- To find the identity of $X(OH)_2$ (a Group II metal hydroxide) by determining its solubility from a titration with $0.05 \text{ mol dm}^{-3} \text{ HCl}$.

Manipulation

- Filter the $X(OH)_2$ solution to remove the undissolved solid.
- Pipette 25 cm^3 of this solution into a clean conical flask.
- Add two or three drops of phenolphthalein indicator to this.
- Prepare the $0.05 \text{ mol dm}^{-3} \text{ HCl}$ in the burette.
- Run the HCl slowly into the conical flask whilst swirling.
- Carefully titrate until the end point is reached. Adding the HCl dropwise when the colour is about to change.
- Repeat until concordant results are obtained.

Data

Solubilities of some metal II hydroxides measured at 18° C given as $\text{g}/100\text{cm}^3$.



Assessment Criteria

You will be assessed on Manipulation, Data Collection, Data Processing, Conclusion and Evaluation.

Data Collection

Observations:

When I was filtering the $X(OH)_2$ solution into the beaker using a piece of filter paper and a funnel, I realised the solute was still a bit cloudy and murky. This meant that some of the undissolved solid was present in the filtered solution.

During the first experiment conducted using the burette to add the hydrochloric acid into the conical flask filled with the filtered solution and three drops of phenolphthalein indicator, I realised the colour change altered swiftly from dark purplish pink to colourless. This meant the neutralisation took place rapidly. I then took this into account when I repeated the experiment and added the hydrochloric acid drop by drop.

Table of Results:

Titration	Volume of $X(OH)_2$ Solution (cm^3)	Volume of Hydrochloric Acid at Beginning (cm^3)	Volume of Hydrochloric Acid at Ending (cm^3)	Difference
1	25	3.00	14.75	11.75
2	25	14.75	25.90	11.15
3	25	25.90	37.05	11.15

Other Important Data:

- There was three drops phenolphthalein indicator in each conducted experiment.
- The concordant results are 11.15 cm^3 .
- The burette filled with hydrochloric acid has a molarity of 0.05 mol dm^{-3} .

Quantitative Uncertainties:

- Burette ~ the burette can only be read accurately to every $\pm 0.1\text{ cm}^3$.
- Pipette ~ the pipette can only be read accurately to every $\pm 0.05\text{ cm}^3$.

excellent!!

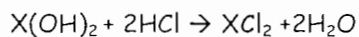
Clear and well presented.

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Teacher	
Moderator	

Assessment - Solubility of $X(OH)_2$

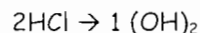
Data Processing/Presentation ~>

The balanced equation should look like the one below:



Calculations:

$$\begin{aligned} \text{Moles of HCl} &= 0.05 \times 11.15 \text{ cm}^3 / 1000 \\ &= 5.575 \times 10^{-4} \end{aligned}$$



Therefore $HCl \rightarrow 1/2(OH)_2$

$$\begin{aligned} \text{Moles of } X(OH)_2 \text{ in } 25 \text{ cm}^3 &= 5.575 \times 10^{-4} \times 1/2 \\ &= 2.7875 \times 10^{-4} \end{aligned}$$

$$\begin{aligned} \text{Moles of } X(OH)_2 \text{ in } 100 \text{ cm}^3 &= 2.7875 \times 10^{-4} \times 4 \\ &= 1.115 \times 10^{-3} \end{aligned}$$

MOLAR MASSES ~>

- o $Be(OH)_2 = 9.01 + 34 = 43.01$
- o $Mg(OH)_2 = 24.31 + 34 = 58.31$
- o $Ca(OH)_2 = 40.08 + 34 = 74.08$
- o $Sr(OH)_2 = 87.62 + 34 = 121.62$
- o $Ba(OH)_2 = 137.34 + 34 = 171.34$

MASSSES OF METAL HYDROXIDE ~>

- o $Be(OH)_2 = 1.115 \times 10^{-3} \times 43.01 = 0.048$
- o $Mg(OH)_2 = 1.115 \times 10^{-3} \times 58.31 = 0.065$
- o $Ca(OH)_2 = 1.115 \times 10^{-3} \times 74.08 = 0.083$
- o $Sr(OH)_2 = 1.115 \times 10^{-3} \times 121.62 = 0.136$
- o $Ba(OH)_2 = 1.115 \times 10^{-3} \times 171.34 = 0.191$

included % errors here
to show uncertainty

Table of Results for Comparison:

CONCLUSION

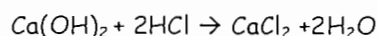
Metal Hydroxide	Solubilities given as g/100cm ³	Masses calculated as g/100cm ³
$Be(OH)_2$	0.000	0.048
$Mg(OH)_2$	0.001	0.065
$Ca(OH)_2$	0.17	0.083
$Sr(OH)_2$	0.77	0.136
$Ba(OH)_2$	3.7	0.191

Conclusions and Evaluation ~>

At the bottom of the previous page is a table showing the solubilities given as g/100cm³ and my calculated results for each metal II hydroxides. As it can be seen, none of my calculated results are relatively close to the solubilities given. This is mainly because of the inaccuracy of the molarity given for the hydrochloric solution. The molarity given was 0.05cm³. This value was is only to one significant figure and so it wasn't a very specific number to use for precise calculations.

Reading off the results from my table in the previous page, I can see that the mass for calcium hydroxide is the closest to its solubility given. This then allows me to identify which metal is X, which is calcium.

Now that X has been identified, the equation can be properly written similar to the one below:



In the experiment conducted, hydrochloric acid was added to react with calcium hydroxide. In the reaction, the calcium bonded with the chlorine particles which came from the hydrochloric acid. The hydroxide also bonded with the hydrogen particles which were left over from the hydrochloric acid, to produce water molecules. In the end of the experiment, calcium chloride and water is produced in the solution.

This was acid + alkali neutralisation. Phenolphthalein tells us when the solution is neutral. As usual, using a pipette and a burette may cause some human errors, as the volume collected may not be precise. Another possible error in my experiment which may have occurred was when I was adding the hydrochloric acid using the burette into the conical flask of calcium hydroxide with the three drops of phenolphthalein indicator. When I was adding the acid through the burette for the first time, I realised that the solution changed colours rapidly when being neutralised. There wasn't a gradual change in colour (dark pinkish purple to clear). It switched from a bright pink one second to a clear solution the next. When I repeated the experiment, I tried to be extremely careful when adding the acid, only allowing a drop to flow through the burette each time. However, this might still not have been accurate enough because the colour change was still very abrupt and the neutralisation may have taken place any time during this.

The chief error is the inaccuracy of the molarity given, as briefly explained above. Since the accuracy was only given to one significant figure this wasn't precise enough for the calculations to be exact, or close to the solubilities given for a proper comparison. They two values for each metal varied such that the closest values had a 0.087cm³ difference. As it can be seen, the vague figure for the molarity affected the results greatly.

If I were to repeat the whole assessment, I would find out the actual molarity of the hydrochloric acid, or at least have the number with two or three figures at the least. This would improve the results and the calculations and make comparisons a lot easier and more exact. I think I will also need to be more careful with the number of drops of hydrochloric acid I let flow through the burette especially during the last several seeps. This will hopefully strengthen accuracy as I hope to be able to measure an even more accurate reading of hydrochloric acid used.

- filtration
- temperature of solution.

No instructions provided

10

AQUEOUS TRANSITION METAL CHEMISTRY

precipitates?

Data Collection

Observations:

Transition Metal	Reaction with:				
	Sodium Hydroxide	Ammonia Solution	Ammonia	Hydrochloric Acid	Sodium thiocyanate Solution
Copper	Before: Blue During: Solid formed, pale blue After Excess: Deeper blue	Before: Blue During: Dark blue After Excess: Light blue	Before: Blue During: Light blue solid formed After Excess: Deep Blue	Before: Blue During: Aqua After Excess: Green liquid	Not required
Cobalt	Before: Pink During: Dark blue/green After Excess: Grey	Before: Pink During: Light blue After Excess: Green	Before: Pink During: Green/blue After Excess: Green/blue	Before: Pink During: Green After Excess: Green	Not required
Iron (II)	Before: Light green During: Reddish brown precipitate After Excess: Orange	Not required	Not required	Not required	Before: Light green During: Black/deep purple After Excess: Clear
Iron (III)	Before: Yellow During: Amber After Excess: Light Brown	Not required	Not required	Not required	Before: Yellow During: Black/deep purple After Excess: Clear

Copper Reactions

Copper + Sodium Hydroxide → Pale blue precipitate + Sodium Hydroxide → Deeper blue solution ~~✗~~

Copper + Ammonia Solution → Dark blue precipitate + Ammonia Solution → Light blue solution

Copper + Ammonia → Light blue precipitate + Ammonia → Deep blue solution

Copper + Hydrochloric Acid → Aqua + Hydrochloric Acid → Green solution

Cobalt Reactions

Cobalt + Sodium Hydroxide → Dark blue/green precipitate + Sodium Hydroxide → Grey solution

Cobalt + Ammonia Solution → Light blue precipitate + Ammonia Solution → Green solution

Cobalt + Ammonia → Green/blue precipitate + Ammonia → Green/blue solution

Cobalt + Hydrochloric Acid → Green precipitate + Hydrochloric Acid → Green solution

Iron (II)

Iron + Sodium Hydroxide → Reddish brown precipitate + Sodium Hydroxide → Orange solution

Iron + Sodium thiocyanate Solution → Black deep purple + Sodium thiocyanate Solution → Clear solution

Iron (III)

Iron + Sodium Hydroxide → Amber precipitate + Sodium Hydroxide → Orange solution

Iron + Sodium thiocyanate Solution → Black deep purple + Sodium thiocyanate Solution → Clear solution

Conclusion & Evaluation

There have been many sources of error and weaknesses which may have affected the procedure and the results. The main error is the measurements and the amount of each solution put together to react. The amount of the aqueous transition metals and also the amount of solutions added to each metal might have affected the reaction before and after the 'excess' testing. For example, when the observations taken 'during' the reaction (meaning before the excess was added) are the same as the 'after excess' observations. This may be the result of having put in too much of the solution into the aqueous transition metal, so the colour after excess will be the same as the colour recorded before the excess was added. This error can explain the odd reaction of Cobalt and Hydrochloric acid.

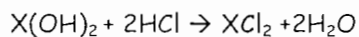
Another source of error could be the cleanliness of the apparatus used. Impurities and other substances could have altered the reaction or slowed it down. When slowed down, the reaction will need more of excess to achieve the same rate of reaction as the other solutions. So

You need to explain why you get the colour changes!

Assessment - Solubility of $X(OH)_2$

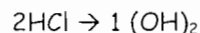
Data Processing/Presentation ~>

The balanced equation should look like the one below:



Calculations:

$$\begin{aligned} \text{Moles of HCl} &= 0.05 \times 11.15 \text{ cm}^3 / 1000 \\ &= 5.575 \times 10^{-4} \end{aligned}$$



Therefore $HCl \rightarrow 1/2(OH)_2$

$$\begin{aligned} \text{Moles of } X(OH)_2 \text{ in } 25 \text{ cm}^3 &= 5.575 \times 10^{-4} \times 1/2 \\ &= 2.7875 \times 10^{-4} \end{aligned}$$

$$\begin{aligned} \text{Moles of } X(OH)_2 \text{ in } 100 \text{ cm}^3 &= 2.7875 \times 10^{-4} \times 4 \\ &= 1.115 \times 10^{-3} \end{aligned}$$

MOLAR MASSES ~>

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to show uncertainty

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Metal Hydroxide	Solubilities given as g/100cm ³	Masses calculated as g/100cm ³
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$Ba(OH)_2$	3.7	0.191

in some cases where the observations between 'during' the reaction and 'after excess' did not vary, this error may have had a part. Examples are cobalt reactions with ammonia and hydrochloric acid.

An additional fault which might have given the same problem (mentioned above) to all of the tests is when I mis-read the instructions and *further* diluted the solutions what have already been diluted (sodium hydroxide, ammonia solution & ammonia). The dilution of these means I possibly needed to add more of solutions, however, if *all* tests were diluted, the test can still be considered fair. The only factor is the *extent* of the dilution which may have affected observations.

A common factor that often cannot be controlled is the temperature. The temperature can greatly affect the rate at which the solutions react and so the excess needed to be reacted will vary.

To improve the experiment I would try and complete multiple trials to make the experiments more accurate, to do this I should keep the previous trial or at least one trial to make comparisons to. To accomplish this, time management is important so I will have to concentrate on that and plan more effectively. Although sometimes it cannot be prevented, temperature changes, another factor which should be kept the same in order to have a fair test. However, the cleanliness of the materials used can be ensured by washing all test tubes and pipettes so that all reactions are not delayed or altered in anyway. Most importantly, the controlling of measurements and amounts of solutions used in each test, I believe this have been the biggest error in this investigation. Each substance (solution) should be measured accurately and then added to each other. And lastly, the instructions have to be read properly in the future for experiments to be fair and produce accurate results.

Me	DC	CE
teacher		
moderator		

SL &
HL

(11)

DETERMINING THE ENTHALPY CHANGE OF A REACTION

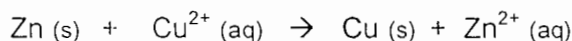
ASSESSMENT

Teacher Instructions

Data Collection	Collecting and recording raw data Organizing and presenting raw data		
Data Processing and Presentation	Processing raw data Presenting processed data		
Conclusion and Evaluation	Drawing conclusions Evaluating procedure(s) and results Improving the investigation		
Manipulative skills	Carrying out techniques safely Following a variety of instructions		

AIM

The purpose of this experiment is to determine the enthalpy change for the displacement reaction:



INTRODUCTION

By adding an excess of zinc powder to a measured amount of aqueous copper(II) sulphate, and measuring the temperature change over a period of time, you can then calculate the enthalpy change for the reaction.

Literature value = - 217 kJmol⁻¹

REQUIREMENTS

- Safety spectacles
- 100- ml graduated cylinder
- Balance
- Styrofoam cup
- Stirring Rod
- Weighing Paper
- 250- ml Beaker
- Spatula
- Zinc Powder
- 1.00 M CuSO₄ (harmful if swallowed)
- CBL System
- TI Graphing Calculator
- Vernier Temperature Probe

DC DPP CE

Me			
teacher			
Moderator			

PROCEDURE

- 1) Obtain and wear safety glasses and an apron.
- 2) Plug the temperature probe into the adapter cable in Channel 1 of the CBL System. Use the link cable to connect the CBL System to the TI Graphing Calculator. Firmly press in the cable ends
- 3) Turn on the CBL unit and the calculator. Start the CHEMBIO program and proceed to the MAIN MENU.
- 4) Set up the calculator and CBL for one temperature probe and a temperature calibration.
 - Select SET UP PROBES from the MAIN MENU.
 - Enter "1" as the number of probes.
 - Select TEMPERATURE from the SELECT PROBE menu.
 - Enter "1" as the channel number.
 - Select USE STORED from the CALIBRATION menu.
- 5) Set up the calculator and CBL for data collection.
 - Select COLLECT DATA from the MAIN MENU.
 - Select TIME GRAPH from the DATA COLLECTION menu.
 - Enter "15" as the time between samples, in seconds.
 - Enter "50" as the number of samples (the CBL will collect data for total of 12.50 minutes).
 - Press ENTER. Select USE TIME SETUP to continue. If you want to change the sample time or sample number, select MODIFY SETUP.
 - Enter "0" as the minimum temperature (Y min).
 - Enter "100" as the maximum temperature (Y max).
 - Enter "10" as the temperature increment (Y sci).
 - Do not start collecting data until instructed to do so in Step 9.
- 6) Use a utility clamp and a slit stopper to suspend a temperature probe from a ring Stand. Place a Styrofoam cup into a 250 ml beaker. Measure out 25.0 ml of 1.0 M CuSO_4 into the styrofoam cup. Lower the temperature probe into the solution.
- 7) Weigh about 6 gms of Zinc powder in the weighing paper. Since this is an excess, there is no need to be accurate.
- 8) Press ENTER to begin collection data and obtain the initial temperature, t_1 . It may take several seconds for the temperature probe to equilibrate at the temperature of the solution. After seven or eight readings at the same temperature (t_1) have been obtained, add the Zinc powder to the solution. Use a stirring rod to stir the cup contents until a maximum temperature has been reached and the temperature starts to drop. Record the maximum temperature, t_2 . After 12.5 minutes, data collection is completed ("DONE" appears on the CBL screen)
- 9) Discard the solution as directed by your teacher.

DPP

CE

C

C

(3)

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C

(3)

Jerry Li
Partner: Michelle Kao
February 16, 2006

(11)

Determining the Enthalpy Change of A Reaction

Data Collection:

Qualitative:

Zinc, a solid dark gray powder, was mixed with copper (II) sulphate, a blue aqueous solution. These two reactants formed a dark gray solution. During the reaction, the solution was bubbling, and heat (gas) was produced from the reaction, signifying that the reaction was exothermic. The temperature increased extremely fast when the zinc was added to the copper (II) sulphate, and then after reaching its maximum temperature, it gradually decreased. Since the solution was very a very dark color, the solid zinc powder was not visible anymore.

The reaction between zinc and copper (II) sulphate formed a dark gray solid (copper), which settled at the bottom of the Styrofoam cup.

Excess zinc could be seen at the sides of the Styrofoam cup after the reaction was complete, meaning the zinc was the excess reagent in the reaction.

Did the blue copper sulfate solution change color?

Quantitative:

Amount of $\text{CuSO}_4(\text{aq})$ used: $25.0 \text{ mL} \pm 0.5 \text{ mL}$

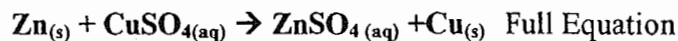
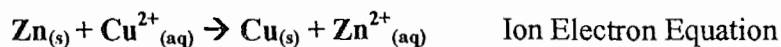
Amount of $\text{Zn}_{(\text{s})}$ used: $6.074 \text{ g} \pm 0.001 \text{ g}$

Table 1. Temperature of the reaction solution between zinc and copper (II) sulphate at fifteen-second intervals.

Time of Experiment (s)	Temperature of Solution ($^{\circ}\text{C}$) $\pm 0.0001^{\circ}\text{C}$
15	22.4091
30	22.4318
45	22.3636
60	22.3636
75	22.3636
90	22.4545
105	22.3409
120	23.4048
135	48.0588
150	58.1034
165	60.4815
180	61.1852
195	60.2222
210	59.4286
225	58.6207
240	57.7931
255	57.0345
270	56.5333
285	55.1667
300	54.2581
315	53.1875
330	52.2424
345	51.5152
360	50.5294
375	49.9706
390	49.4412
405	48.6176
420	48.0882
435	47.3889
450	46.6511
465	46.1944
480	45.7297
495	45.2432
510	44.6216
525	44.1351
540	43.7268
555	43.1842
570	42.8947
585	42.3684
600	42.2368
615	41.7179
630	41.2564
645	41.0513
660	40.7436
675	40.3333
690	40.0769
705	39.7750
720	39.4000
735	39.1000
750	38.8250

Data Processing:

Calculating the limiting/excess reagent:



Actual moles of CuSO₄

$$V(\text{CuSO}_4) = 25.0 \text{ mL}$$

$$C(\text{CuSO}_4) = 1 \text{ mol dm}^{-3}$$

$$n(\text{CuSO}_4) = c \times v$$

$$= 1 \text{ mol dm}^{-3} \times (25/1000) \text{ dm}^3$$

$$= 0.025 \text{ mol} \quad \checkmark$$

Actual Moles of Zn

$$m(\text{Zn}) = 6.0 \text{ g}$$

$$M(\text{Zn}) = 65.37 \text{ g mol}^{-1}$$

$$n(\text{Zn}) = m/M$$

$$= (6\text{g}) / (65.37 \text{ g mol}^{-1})$$

$$= 0.092 \text{ mol} \quad \checkmark$$

Required moles of CuSO₄

$$n(\text{CuSO}_4) : n(\text{Zn})$$

$$1 : 1$$

$$x : 0.092$$

$$x = 0.092 \text{ mol}$$

Required moles of Zn

$$n(\text{CuSO}_4) : n(\text{Zn})$$

$$1 : 1$$

$$0.025 : x$$

$$x = 0.025 \text{ mol} \quad \checkmark$$

Since actual mol of Zn (0.092 mol) is greater than required mol of Zn (0.025 mol), **Zn is the excess reagent**

Since actual mol of CuSO₄ (0.025 mol) is less than required mol of CuSO₄ (0.092 mol), **CuSO₄ is the limiting reagent** \checkmark

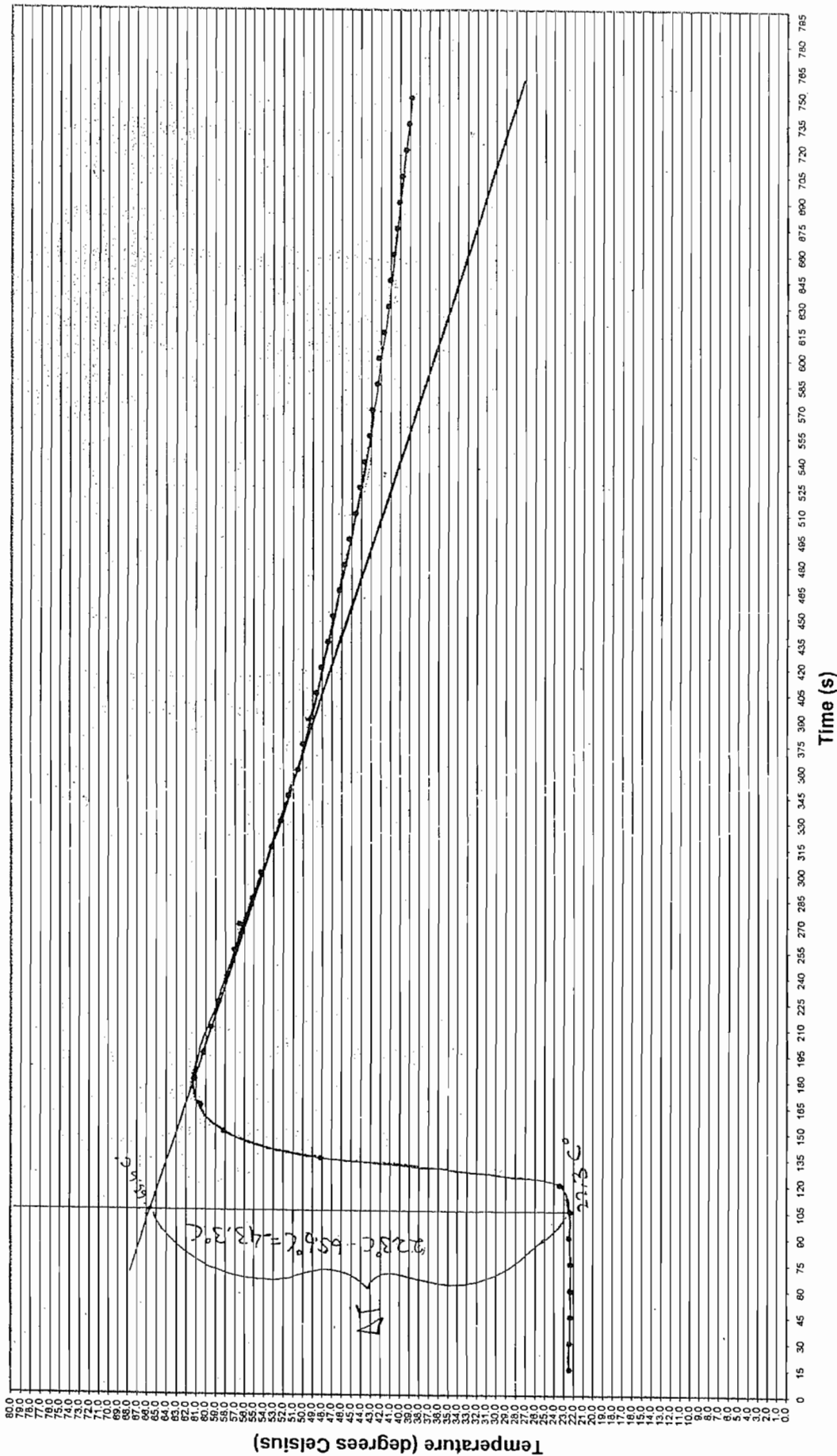


Figure 1. Temperature of a copper(II) sulphate solution reacted with zinc at fifteen second intervals,

°C use symbol

4

70

1000/01/17

Calculating the Enthalpy Change:

$$\text{Mass of aqueous reactant (m)} = 25.0 \text{ g} \pm 2.0\%$$

$$\text{Specific heat capacity (c)} = 4.18 \text{ Jg}^{-1}\text{K}^{-1}$$

$$\Delta T = 22.3^\circ \text{C} (\pm 0.5^\circ \text{C}) - 65.6^\circ \text{C} (\pm 0.5^\circ \text{C})$$

$$= -43.3^\circ \text{C} \pm 1.0^\circ \text{C}$$

$$= -43.3^\circ \text{C} \pm 2.3\%$$

$$n(\text{limiting reagent}) = 0.025 \text{ mol} \pm 2.0\%$$

$$\Delta H = (m \times c \times \Delta T) / (n(\text{limiting reagent}))$$

$$= (25.0 \text{ g} \times 4.18 \text{ Jg}^{-1}\text{K}^{-1} \times -43.3^\circ \text{C}) / (0.025 \text{ mol})$$

$$= -180994 \text{ Jmol}^{-1} \pm 6.3\%$$

$$= -181 \text{ kJ mol}^{-1} \pm 6.3\%$$

(m) is the mass of the aqueous reactant, CuSO_4 , which we measured initially. The specific heat capacity (c) is given. The change in temperature was calculated through extrapolation of the graph shown in Figure 1. This change in temperature is negative, because the reaction was exothermic as heat was lost to the environment. This negative change in temperature also causes the change in enthalpy to be negative. The moles of the limiting reagent were calculated in the above procedure "calculating the limiting/excess reagent".

Calculating % Uncertainties:

volume	$\pm (0.5 \text{ mL} / 25.1 \text{ mL}) \times 100 = \pm 2.0\%$
mass	$\pm (0.001 \text{ g} / 6.074 \text{ g}) \times 100 = \pm 0.02\%$
Temp	$\pm (1.0^\circ \text{C} / 43.3^\circ \text{C}) \times 100 = \pm 2.3\%$
Total	$\pm 2.0\% \pm 0.02\% \pm 2.3\% = \pm 4.3\%$

This could be presented a little more clearly

Conclusion:

The purpose of this experiment, which was to determine the enthalpy change for the displacement reaction, $\text{Zn}_{(s)} + \text{Cu}^{2+}_{(aq)} \rightarrow \text{Cu}_{(s)} + \text{Zn}^{2+}_{(aq)}$, was achieved by adding an excess of zinc powder to a measured amount of aqueous copper (II) sulphate, and measuring the temperature change over a period of 12.5 minutes. By figuring out the temperature change of the reaction, as well as the number of moles of the limiting reagent (CuSO_4), this information was applied to the formula $\Delta H = (m \times c \times \Delta T) / (n(\text{limiting reagent}))$ in order to determine the enthalpy change for the reaction

Describe
your
graph?

a larger change in enthalpy. Through extrapolation, a temperature change of $-43.3^{\circ}\text{C} \pm 2.3\%$ was calculated, which was used to determine the change in enthalpy, which was $-181\text{ kJ mol}^{-1} \pm 6.3\%$.

$$\begin{aligned}\% \text{ Difference} &= (|\text{Experimental Value} - \text{Literature value}| / \text{Literature Value}) \times 100 \\ &= (|-181\text{ kJ mol}^{-1} - (-217\text{ kJ mol}^{-1})| / -217\text{ kJ mol}^{-1}) \times 100 = 16.6\%\end{aligned}$$

Evaluation:

$$\% \text{ Difference} = 16.6\%$$

$$\% \text{ Uncertainty} = \pm 4.3\%$$

Since the % difference was greater than the % uncertainty, the main source of error in this lab was systematic errors. The main systematic error was the loss of heat energy of the reaction to the ^{surroundings} environment. Since the reaction container was not insulated adequately, the reaction lost heat energy to its surroundings. This made the change in temperature less than accepted and thus it decreased the enthalpy change. This error can be minimized by ensuring the reaction container has an insulating lid that will prevent the heat loss. Another method, which could minimize this error, which was performed in the data processing, was to plot a temperature versus time graph and extrapolation was used to determine the instantaneous change in temperature. However, this extrapolation is still unreliable because the extrapolation was drawn by hand, and the line of best fit was hard to determine by hand. To improve the accuracy of the extrapolation, technology should be used. ^{ε increased the % difference} ^{? what sort of technology?}

Another potential source of systematic error was that the reaction was stirred too slowly. This would increase the time taken for the reaction to occur and this extra time would thus also increase the amount of heat lost. Since there would be more heat lost, the change in temperature would be lower, and thus the enthalpy change would be less as well. Stirring rapidly when the solid reactant is added into the aqueous reactant can eliminate this error.

Also, when the reaction reached the maximum temperature, and started to lose heat, after a while it began to absorb heat from the environment. This absorption of heat caused the temperature decrease to become less, so the slope of the line

representing the decrease in temperature because less steep. This caused trouble during extrapolation because it was difficult to determine a line of best fit, decreasing the accuracy of the extrapolation. Therefore, the line of best fit had to be drawn for the temperature decrease before the solution started to absorb heat, in order to try to improve the accuracy. A better insulated container would have also once again minimized this error.

There were also assumptions made that would affect the results. It was assumed that the reaction was carried out under standard conditions of 1 atm and temperature of 298 K. It was probable that the reaction was not carried out under these exact standard conditions, and since all literature values are determined under standard conditions, this would alter the results depending on what the conditions actually were. To get rid of this potential source of error, the experiment must be carried out under standard conditions. ~~Not possible to do in a school science lab~~ Also, an assumption was made that the specific heat capacity of the CuSO_4 solution was equal to that of water ($4.18 \text{ Jg}^{-1}\text{K}^{-1}$). Since the solution was not water, the specific heat capacity of the solution would have then been inaccurate, altering the results as well. If the specific heat capacity of CuSO_4 were less than that of water, the calculated change in enthalpy would be higher than it should be. If the specific heat capacity of CuSO_4 were greater than that of water, the calculated change in enthalpy would be lower than it should be. To eliminate this error, the actual heat capacity of CuSO_4 has to be calculated and used in the calculations to attain the change in enthalpy. ✓

This experiment was not highly valid due to the main systematic errors that were present in the experiment. By taking the steps necessary to eliminate these systematic errors would significantly increase the validity of this experiment. Also, steps should be taken to ensure the reaction occurs under standard conditions of 1 atm and temperature of 298 K. Repeating this experiment several times can also increase the reliability of this experiment. Through many different enthalpy change calculations for the reaction between zinc and copper (II) sulphate, the calculations can be averaged to attain a more reliable result.

Uncertainties

Key words: absolute, relative, random, systematic, precise, accurate, reliable

Every measurement is made with limited accuracy and therefore has an uncertainty associated with it. Every calculated result also has an uncertainty that it related to the measured data used to calculate it.

The **absolute** uncertainty/error is the actual error associated with a measured quantity.

With electronic devices for example an electronic balance the error is the number of significant figures in the reading. For example if an electronic balance measures to $1/10^{\text{th}}$ of a gram its absolute uncertainty is $\pm 0.1\text{g}$. We express this in the following way: $3.5 \pm 0.1\text{g}$. This means that the true value lies somewhere between 3.4 and 3.6 g.

Measuring devices with scales can usually be estimated to half a division on the scale. For example a measuring cylinder that has a scale with intervals (divisions) of 1ml will have an absolute uncertainty of $\pm 0.5\text{ml}$ after taking into account the estimation.

All measurements should have their associated absolute error/uncertainty. The number of decimals places in the measurement should be consistent with the uncertainty. To minimize absolute uncertainty the most accurate measuring instrument available should be used.

Relative uncertainty expresses the absolute uncertainty as a percentage ($\Delta x/x \times 100$) or a fraction ($\Delta x/x$).

For example $m(\text{Fe}) = 3.5 \pm 0.1\text{g}$ The relative error is $(0.1 \div 3.5) \times 100 = 3\%$

$$m(\text{Fe}) = 3.5\text{g} \pm 3\%$$

Processing the data in an experiment involves calculating the relative uncertainty. This process is called combining or propagating uncertainties.

Addition and subtraction of absolute uncertainties

The final uncertainty that is the result of addition and subtraction is the sum of the absolute uncertainties provided that the data is converted to the same units.

Sample calculation

If the $m(\text{CuO}) = 1.99 \pm 0.01\text{g}$ and the $m(\text{Cu}) = 1.40 \pm 0.01\text{g}$

$$m(\text{O}) = 1.99 \pm 0.01\text{g} - 1.40 \pm 0.01\text{g}$$

$$= 0.59 \pm 0.02\text{g}$$

$$= 0.59 \pm 4\% \quad (0.02/0.59 \times 100)$$

Multiplication and division of absolute uncertainties in calculations

The overall uncertainty that is the result of multiplication and division is the sum of the relative percentage uncertainties.

Sample calculation

$$\begin{aligned}\% \text{H}_2\text{O lost} &= \frac{0.706 \text{ g} \pm 0.1 \%}{1.914 \text{ g} \pm 0.3 \%} \times 100 \\ &= 36.9 \pm 0.4 \% (0.1 + 0.3)\end{aligned}$$

Absolute and Relative uncertainties are expressed to one significant figure.

NOTE:

The following numbers are considered infinitely accurate and do not affect the number of significant figures in an answer because they are an exact count and not a measured number.

1. Conversion factors. For example converting cm^3 to dm^3 you divide by 1000.
2. Glassware sizes. For example a 250 cm^3 volumetric flask.
3. Counted numbers. For example the number of moles of hydrogen atoms in one mole of H_2O is 2.

Accuracy

Accuracy can be shown in two ways.

1. Percentage Error

This is the percentage difference between the measured result in the experiment and the actual / accepted / true / literature / correct / expected value.

$$\% \text{ Error} = \frac{\text{Measured value} - \text{Actual value}}{\text{Actual value}} \times 100$$

2. Uncertainty in a measurement.

Expressed by stating the absolute \pm uncertainty associated with a measurement or stated implicitly by the number of significant figures given.

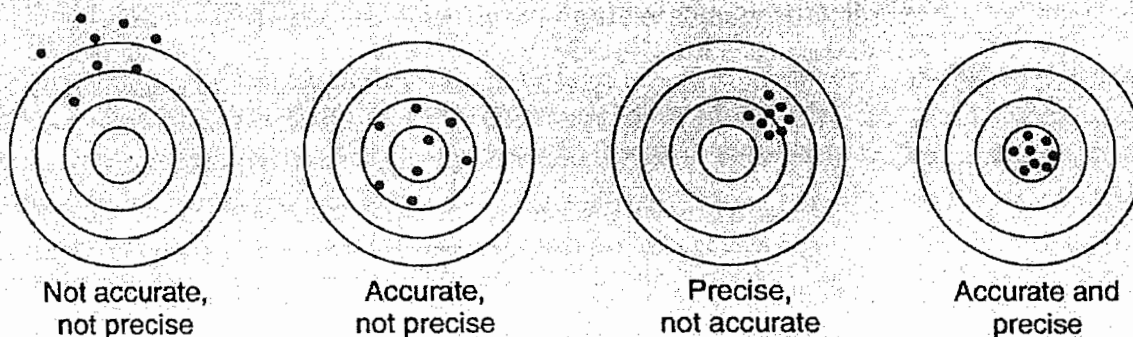
For example:

- an electronic balance that measures to 0.001 g , has an uncertainty of $\pm 0.001 \text{ g}$. This balance is more accurate than one which measures to 0.1 g and has an uncertainty of $\pm 0.1 \text{ g}$.
- Using Avogadro's number as 6.023×10^{23} is more accurate than using 6×10^{23} because it has more significant figures.

Precision

A measure of the range of values found. Precision can be increased by repeating / reproducing the measurements. A good experiment should endeavor to be as accurate and precise as possible. However, good precision does not necessarily imply that there are high levels of accuracy.

Figure Precision and Accuracy Illustrated



Error

The uncertainty in a final experimental result arises from two types of error, systematic and random.

Systematic errors occur in each measurement as a result of the measuring process. They are errors that consistently make the results either too big or too small. Systematic errors can't be analyzed mathematically because all of the data is off in the same direction. They persist throughout an experiment and can't be diminished by taking repeated measurements. Systematic errors can result in high precision, but poor accuracy.

A well designed experiment will minimize systematic errors. Where this is not possible, the errors should be investigated and suggestions how to overcome or compensate for them made. However, small systematic errors will always be present no matter how good the design. For instance, no instrument can ever be calibrated perfectly. The discussion of systematic error is made in the evaluation section of a lab report.

Examples include:

- Fluctuations on electronic devices like an electronic balance, pH probe, temperature probe or conductivity meter.
- Loss of heat from a reaction, if temperature is being measured.
- Loss of reactant or product
- Faulty instruments that are not calibrated properly, for example an electronic balance that reads 0.05g too high.
- Human factors, for example the incorrect reading of the end point in a titration due to the experimenter being color blind.
- Procedural error in the use of the equipment.
- Flaws in the experimental design.
- Using the wrong instrument for the measurement, for example using a ruler to measure the diameter of a sphere when a caliper would be more appropriate.
- Parallax error in reading a scale on a burette or measuring cylinder.
- The closeness and coarseness of the graduations on a scale.

- Theoretical - due to simplifications of the model or approximations made. For example in the calculation of an enthalpy change the specific heat capacity is assumed to be that of water. Theoretical errors will mean that the theoretical and experimental results will consistently disagree.

Random errors occur in all measurements and are fluctuations in the measured data in either direction (too big and too small). Random errors result in the experimenter's inability to take the same measurement in exactly the same way to get exactly the same number. They can be minimized by taking a large number of repeated measurements, and then taking the average/mean of the results. Obvious outliers are eliminated. Random errors affect the precision of a result.

If the % Error > % uncertainty, systematic errors are the main source of error. The sources of these systematic errors need to be discussed in the evaluation section of the lab report.

If the % Error < % uncertainty, random errors are the main source of error. To overcome this problem the experiment needs to be repeated (tried) a larger number of times.

A **valid** experiment is one that fairly tests the hypothesis, all variables are kept constant apart from those being investigated, all systematic errors have been eliminated (or minimized as much as possible) and random errors are reduced by taking the mean of multiple repeated measurements.

The degree to which the difference between results can be relied upon is called *statistical validity*. The statistical significance of a result depends upon the number of sampled data points, the size of the effect, and the amount of variation between measurements. Statistical validity can be improved with increased samples, and by creating as large an effect as possible.

Reliability refers to **repeatability** or reproducibility. If an experiment is repeated many times (the trials) and gives identical results it is called reliable. Reliable results result from a valid experiment. However an experiment could produce reliable results but it would be invalid if incorrect calculations were done.

Teacher Instructions

12

Name _____ Date _____

Experiment: Empirical Formula of a Hydrate

Hydrates are ionic compounds (salts) that have a definite amount (moles) of water as part of their structure. The water of hydration is released as water vapor when the hydrate is heated. The remaining salt is known as the anhydrous salt. For example, the accepted formula of hydrated copper sulphate is $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. Every one mole of copper sulphate has six moles of water associated with it. The accepted percentage composition of the water in the hydrate is 36.00%.



Aim

To confirm the empirical formula of copper sulfate hydrate.

IB Assessment

Data Collection	<ul style="list-style-type: none"> Observing (collecting) and recording raw data Organizing and presenting raw data 		
Data Processing & Presentation	<ul style="list-style-type: none"> Processing raw data Presenting processed data 		
Conclusion & Evaluation	<ul style="list-style-type: none"> Drawing conclusions Evaluating procedure(s) and results Improving the investigation 		

Procedure

- Find the mass of a clean crucible and its lid.
- Add approximately 2.000 g of copper sulfate hydrate. Record the exact mass.
- Place the crucible with its lid on a pipe triangle and heat strongly for 10 minutes. Allow it to cool. Consider why the crucible is heated with the lid on.
- Immediately reweigh it when it is cool enough to be held. Consider why the mass of the anhydrous salt be measured immediately upon cooling
- Heat strongly for five minutes, allow to cool, and then reweigh.
- Repeat step 5 until the mass is constant.

Wear safety glasses at all times

Date Practical Work Complete in Class: September 29, 2006

Partner: Henry Huang

Lab Experiment: Composition of a Hydrate**DATA COLLECTION****Quantitative observations**

- ✓ Mass of crucible and its lid = 36.610 ± 0.001 g
- ✓ Mass of copper sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) = 2.053 ± 0.001 g
- ✓ Mass of copper sulfate with crucible and its lid (after first heating) = 37.868 ± 0.001 g
- ✓ Mass of copper sulfate with crucible and its lid (after second heating) = 37.848 ± 0.001 g
- ✓ Mass of copper sulfate with crucible and its lid (after third heating) = 37.844 ± 0.001 g

Qualitative observations**Observations of the substances used:**Copper sulfate pentahydrate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$)-Colour: *Blue*-State: **Solid****Observations noted of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ after it was heated for 10 minutes on a pipe triangle (reaction occurred):**-Colour: *White*-State: **Solid**-Colour change: *Blue (original substance) to White*-Odour change: None recognized-No bubbling but a gas was present: water vapour was released (H_2O was evaporated)

-No loss of solid reactant

Student 12

'When data is processed, the uncertainties associated with the data must also be considered. If the data is combined and manipulated to determine the value of a physical quantity then the uncertainties in the data must be propagated (see topic 11). Calculating the percentage difference between the measured and literature value does not constitute error analysis.'

In order to completely fulfil aspect 3 of Data Collection and Processing student should include treatment of uncertainties and errors with their processed data.

For student 9:

1. Propagate the errors through the calculation.
2. Determine % Difference and % Uncertainty
3. Compare the % Difference and % Uncertainty and comment on the major source of error.

$$1. \quad 36.610 \pm .001 \text{ g}$$

$$2. \quad 2.053 \pm .001 \text{ g}$$

$$3. \quad 37.686 \pm .001 - 36.610 \pm .001$$

$$1.076 \pm .002$$

$$37.648$$

$$36.610$$

$$- \quad 1.038 \pm .002$$

$$37.644$$

$$36.610$$

$$- \quad 1.034 \pm .002$$

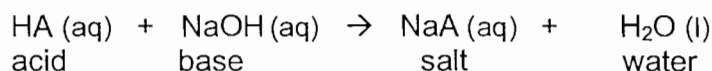
EXPERIMENT: ACID – BASE TITRATION

AIM

Confirm the concentration of a solution of sodium hydroxide by titration against a standard solution of potassium hydrogenphthalate, $C_8H_5O_4K$.

INTRODUCTION

You have already made a standard solution of potassium hydrogenphthalate, a primary standard and an acid. Potassium hydrogenphthalate has the formula $C_8H_5O_4K$, but we can simplify the formula to HA. This simple formula is often used to represent an acid with a complicated structure.



The acid reacts with the base/alkali sodium hydroxide to produce a salt and water. This type of chemical reaction is called a double replacement or neutralization reaction.

To indicate when the reaction between the two colorless solutions is complete (called the stoichiometric point or equivalence point) the indicator phenolphthalein is used. Phenolphthalein is colorless in acid and pink in base/alkaline solution. The point at which the addition of one drop (or even less) changes the solution from colorless to just faintly pink is called the end-point and, in this case, shows that the reaction is just complete.

ASSESSMENT

Data Collection	<ul style="list-style-type: none"> Observing (collecting) and recording raw data Organizing and presenting raw data
Data Processing & Presentation	<ul style="list-style-type: none"> Processing raw data Presenting processed data
Conclusion & Evaluation	<ul style="list-style-type: none"> Drawing conclusions Evaluating procedure(s) and results Improving the investigation
Manipulative skills	<ul style="list-style-type: none"> Carrying out techniques safely Following a variety of instructions

APPARATUS AND MATERIALS

- Safety glasses and lab apron
- Filter funnel, small
- Burette, 50 cm^3 , and stand
- Two beakers, 100 cm^3
- Sodium hydroxide solution (0.10 M NaOH)
- Pipette, 25 cm^3
- Pipette filler
- Standard potassium hydrogenphthalate solution

- (prepared in previous lab)
- Four conical flasks, 250 cm³
 - Phenolphthalein indicator solution
 - Wash bottle of distilled water

SAFETY

Sodium hydroxide solution is very corrosive. Even when dilute it can damage your eyes. Therefore you must wear safety glasses and an apron throughout the experiment.

PROCEDURE

1. Using the funnel, rinse the burette with a little sodium hydroxide solution and then fill it with the same solution. Record the initial burette reading.
2. Using a pipette filler, rinse the pipette with a little potassium hydrogenphthalate solution and carefully transfer 25.0 cm³ of the solution to a clean dry 250 cm³ conical flask.
3. Add two to three drops of the phenolphthalein indicator solution.
4. Run sodium hydroxide solution from the burette into the flask, with swirling, until the solution just turns pink. This first titration may be used as a trial run, because you will probably overshoot the end-point. Record the final burette reading.
5. Refill the burette with the sodium hydroxide solution, and again record the initial burette reading to the nearest 0.05 cm³ (one drop).
6. Using the pipette, transfer 25.0 cm³ of the potassium hydrogenphthalate solution to another clean conical flask. Add two to three drops of the phenolphthalein solution.
7. Carefully titrate this solution to the end-point, adding the sodium hydroxide drop-by-drop when you think the color is about to change.
8. Repeat steps 5, 6 and 7 at least twice more.
9. Empty the burette and wash it carefully immediately after the titration, especially if it has a ground glass tap.
10. Rinse out all the other glassware with water and leave to dry. Finally wash your hands.
11. Determine the average of the two or three most concordant volumes of sodium hydroxide recorded.

ACCURACY

Record the burette readings to the nearest ± 0.05 cm³ (approximately one drop). Consecutive titrations should agree to within ± 0.10 cm³ and, strictly, you should repeat the titration until this is achieved. However, you may have neither the time nor sufficient solutions do this. With practice, your technique will improve so that it is not necessary to do more than four titrations. Calculate the mean of the two (or preferably three) closest consecutive (concordant) readings and quote this also to the nearest ± 0.05 cm³. This does not introduce a fourth significant figure; it merely makes the third figure more reliable (make results more consistent).

Date Practical Work Complete in Class: November 2, 2006

Partners: Tim Kelly and Bert Hootsmans

Lab Experiment: Acid – Base Titration**DATA COLLECTION**Observations of the substances used:

NaOH (sodium hydroxide - base)

- Clear
- Transparent
- Colour: *Colourless*
- State: ~~Liquid~~ solution

 $\text{C}_8\text{H}_5\text{O}_4\text{K}$ (potassium hydrogenphthalate - acid)

- Clear
- Transparent
- Colour: *Colourless*
- State: ~~Liquid~~ solution

remember the
difference between
a solution & a
liquid?

Phenolphthalein (indicator solution)

- Clear
- Transparent
- Colour: *Colourless*
- State: **Liquid**

Colour change at end point: pink

Concentration of potassium hydrogenphthalate = $0.0980 \text{ mol/dm}^3 \pm 0.1\%$ Volume of potassium hydrogenphthalate used in each trial = $25 \pm 0.60 \text{ cm}^3$ 0.0600 cm³

Volume of phenolphthalein used in each trial = 2 drops

Initial pipette reading during each trial = $25.000 \pm 0.060 \text{ cm}^3$

TABLE 1. Rough Titre Reading and Two Closest Consecutive Titre Readings of Sodium Hydroxide and Potassium Hydrogenphthalate Titration

Volume (mm)		Rough Titre	Titre 1	Titre 2	Average of Titres 1 to 3
Initial Burette Reading ($\pm 0.05 \text{ cm}^3$)		0.20	0.00	0.30	$(0.00+0.30)/2 = 0.15$
Final Burette Reading ($\pm 0.05 \text{ cm}^3$)		25.20	24.88	25.20	$(24.88+25.20)/2 = 25.04$
Titre ($\pm 0.10 \text{ cm}^3$) = Final Burette Reading - Initial Burette Reading		25.00	24.88	24.90	$(24.88+24.90)/2 = 24.89$

calculation steps are not shown in table show below

DATA PROCESSING AND PRESENTATION

After the raw data was collected, it was seen that there were only 2 consecutive readings close enough to be used in the calculation of the average.

The 3 titre readings obtained from the titration were $25.00 \pm 0.05 \text{ cm}^3$, $24.88 \pm 0.05 \text{ cm}^3$, and $24.90 \pm 0.05 \text{ cm}^3$. As stated in the accuracy section, the titrations should have been within $\pm 0.10 \text{ cm}^3$, thus, it was evident that $25.00 \pm 0.05 \text{ cm}^3$ could not have been used. $25.00 \pm 0.05 \text{ cm}^3$ differed from $24.90 \pm 0.05 \text{ cm}^3$ by 0.10 cm^3 but differed from $24.88 \pm 0.05 \text{ cm}^3$ by 0.12 cm^3 , and thus, did not fall in the necessary range. $24.88 \pm 0.05 \text{ cm}^3$ and $24.90 \pm 0.05 \text{ cm}^3$ both differed in the tenth digit (0.10) by a value of 0.1, while $25.00 \pm 0.05 \text{ cm}^3$ differed from the other two values in the ones digit (1) by a value of 1 (the difference is too large). Therefore, $25.00 \pm 0.05 \text{ cm}^3$ was left out from the calculation of the mean of the trials.

Student 13

For student 10:

1. Propagate the errors through the calculation.
2. Determine % Difference and % Uncertainty
3. Compare the % Difference and % Uncertainty and comment on the major source of error.

IB Chemistry Internal Assessment

Experiment Title: Activation Energy of Bromide/Bromate.

Conclusion and Evaluation

LEVELS	ASPECTS		
	Drawing conclusions	Evaluating procedures and results	Improving the investigation
Complete	<p>Gives valid conclusion based on correct interpretation of results. E.g.</p> <ul style="list-style-type: none"> Finds and presents literature value for activation energy. (54 KJ mol⁻¹). Explains what activation energy is. Compares practical value with literature value. 	<p>Evaluates limitations and errors. At least 3 are clearly explained. E.g.</p> <ul style="list-style-type: none"> Difficulty in interpreting colour change. Poor graph or line of best fit leads to innaccurate gradient. Difficulty in keeping the temperature constant. Impurities in chemicals can lead to misinterpretation of colour change, or side reactions that affect the rate. 	<p>Clearly states and explains at least 3 relevant improvements to the investigation. E.g.</p> <ul style="list-style-type: none"> Use of spectrometer or standard solution to interpret colour change fairly. Computer generated graph and gradient would improve accuracy. Water bath for controlling the temperature. Higher purity of reactants leads to clearer colour changes.
Partial	States a conclusion that has some validity.	Some obvious limitations and errors are missed.	Suggests only simple improvements.
Not at all	Completely misinterprets the results.	Evaluation is irrelevant.	Improvements are irrelevant.

1

Comments

Molar Mass Citric acid

Student:

INTERNAL ASSESSMENT MARKING FORM APRIL 2005

Teacher:

Data Collection		Assessed	Not Assessed
Raw data (qualitative/quantitative) is recorded appropriately	✓		
including units	✓		
and uncertainties where necessary	✓		
(c) (p) n			
Raw data is presented clearly,	✓		
allowing for easy interpretation	✓		
(c) p n			
comments:			
<div style="display: flex; justify-content: space-between;"> <div> (cc) cp cn pp pn nn </div> <div> (3) 2 1 0 </div> </div>			
GRADE		3	

Data Analysis		Assessed	Not Assessed
The raw data is processed correctly	✓		
to produce results that help interpretation;	✓		
where appropriate, error analysis is included.	✗		
c (p) n			
Data/ results are presented appropriately and effectively;	✓		
where relevant, errors and uncertainties are taken into account	✗		
c (p) n			
comments:			
<div style="display: flex; justify-content: space-between;"> <div>cc cp cn(pp) pn nn</div> <div>3 2 (1) 0</div> </div>			
GRADE		1	

Evaluation		Assessed	Not Assessed
A valid conclusion (based on the correct interpretation of the results) is given;	✓		
with an explanation,			
where appropriate, results are compared with literature values			
c p n			
The procedure (apparatus, materials and method) including limitations, weaknesses or errors in manipulation, is evaluated (discussion of the limitations of data analysis may be included)			
c p n			
Suggestions to improve the investigation following the identification of weakness(es) are stated.			
c p n			
comments			
<div style="display: flex; justify-content: space-between;"> <div>ccc ccp ccn cpp ppp cpn cnn ppn pnn nnn</div> <div>3 2 1 0</div> </div>			
GRADE			

IB Assessment Criteria and Aspects

Criteria: Planning (a)				
Levels	Defining the problem or research question	Formulating a hypothesis or prediction	Selecting variables	Overall Level
Complete (c)	Identifies a focused problem or research question ✓	Relates the hypothesis or prediction directly to the research question and explains it, quantitatively where appropriate	Selects the relevant independent, dependent and controlled variables	ccc: 3
Partial (p)	States the problem or research question but it is unclear or incomplete	States the hypothesis or prediction but does not explain it ✓	Selects some relevant variables ✓	cpp, ccn, ccp: 2 ppp, ppn, cpn, cnn: 1
Not at all (n)	Does not state the problem or research question or repeats the general aim provided by the teacher	Does not state a hypothesis or prediction	Does not select any relevant variables	pnn, nnn: 0
Comments: See Student work				Overall Level: 2

Criteria: Planning (b)				
Levels	Selecting appropriate apparatus or materials	Designing a method for the control of variables	Designing a method for the collection of sufficient relative data	Overall Level
Complete (c)	Selects appropriate apparatus or materials	Describes a method that allows for the control of the variables	Describes a method that allows for the collection of sufficient relative data	ccc: 3
Partial (p)	Selects some appropriate apparatus or materials ✓	Describes a method that makes some attempt to control the variables ✓	Describes a method that allows for the collection of insufficient relative data ✓	cpp, ccn, ccp: 2 ppp, ppn, cpn, cnn: 1
Not at all (n)	Does not select any apparatus or materials	Describes a method that does not allow for the control of the variables	Describes a method that does not allow any relevant data to be collected	pnn, nnn: 0
Comments:				Overall Level: 1

Scoring rubric: completely met = 3 ; partially met = 2 ; not met = 1

1.	Title
	No more than 13 words.
	Incorporates independent and dependent variable. Less detailed than the aim

2.	Planning (a)
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Defining the problem / research question / aim

	Clearly stated in about two sentences.
	Free of procedure and incorporates the independent and dependent variables

Formulating a hypothesis or prediction

	The expected outcome is clearly stated, and directly relates to the aim. It incorporates the dependent and independent variable and is quantifiable.
	A hypothesis, a tentative explanation for the expected outcome is made. The explanation is correctly and fully explained using the appropriate theory/law/concept and written at a level of detail that reflects current chemical knowledge (from class) and at a molecular level. Chemical equations, graphs showing relationships between the independent and dependent variables and calculations are used if appropriate to support the explanation.

Selecting the variables

	<p>List of all the important dependent, independent and controlled variables.</p> <ul style="list-style-type: none"> Independent variable – the factor being investigated or manipulated. Dependent variable(s) – what is measured or the type of numerical data collected about the independent variable. Controlled / constant variables – what is kept constant or remains unchanged between the different experiments into the factor being investigated.
	Variables list includes details on the chemicals, materials and measurements being investigated, measured or held constant. For example quantities (concentration, mass, volume) time intervals, units, sizes, types of equipment.

3.	Planning (b)
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Selecting apparatus and materials

	Complete list of all materials and apparatus used. Include concentrations, amounts of substances and sizes. Alternatively, if more appropriate, a diagram can be drawn. Diagrams should be: 2D if hand drawn and can be 3D if computer generated, drawn with sharp pencil (except if computer generated), a suitable size (about 1/3 rd page), completed functional set ups not individual pieces, called a figure and numbered consecutively with a concise descriptive title is written underneath the diagram, clear, simple, single and narrow lines (no shading), labeled accurately and completely with label lines parallel to one another, horizontal and ruled.
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Method controls the variables

	Method and sequence used is sufficiently clear so that can be easily reproduced by another student. If not, it requires more detail.
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	All the dependent, independent and controlled variables are incorporated correctly (as per variables list) into the procedure. It is explicitly clear how the control of variables will be achieved / monitored. What data is collected and the frequency of collection is clearly stated.
	For chemical reactions, the steps based on stoichiometry (for example - calculation of masses, concentrations, moles, volume) need to be shown.
	How the raw data will be analyzed is described. For example include details of relevant formula for calculations and graphs that will be plotted.

Collection of sufficient relevant data

	Sufficient data on the factor being investigated (independent variable) is collected. For example at least <u>three</u> different temperatures in a rate investigation or data collected over a suitable time frequency.
	The reason for repeated measurements (trials) to improve precision of raw data and reduce random error is stated (even if not carried out).

4. Data Collection

Collecting and recording raw data

	Qualitative data contains sufficient detail on the chemically significant observations only. Include initial color and state of reagents. Evidence of a reaction include: color change, change of state, odor change, gas being produced (and the relative rate at which it is evolved), solid reactant disappears, temperature change, solid is precipitated.
	Sufficient raw quantitative data is collected and recorded. Raw data is actual measured data
	All units of measurement and absolute uncertainties are estimated and that magnitude recorded correctly. The uncertainty on averages is the sum of the absolute uncertainties.

Organizing and presenting raw data

	Raw quantitative data is presented in easily interpretable, organized and labeled table(s). A well organized table will: <ul style="list-style-type: none"> • borders/lines around text and numerical data, • not run over two pages • columns to be compared placed next to one another • called tables and numbered consecutively with a concise descriptive title that relates the measured (dependent) and changed (independent) variables on top of the table • text and data centered • rows and columns are evenly distributed • 11–12 point font size and a consistent font type for electronic tables • correctly placed in document.
	Units of measurement and uncertainties are included in the column heading.
	Consistent and correct use of decimal places and/or significant figures so that there is no variation in the precision of the raw data. The level of precision should be consistent with that of the raw data.

5. Data Processing and Presentation

Processing raw data

	Complete and correct quantitative analysis of the data is carried out. The processed data is appropriate for the nature of the results
	At least one sample per calculation showing the steps involved is shown. Identical calculations do not need to be repeated.
	For repeated trials, the final result for each trial is calculated. Average results are calculated based on the final results of repeated trials. Exclusion of trials / collected data is stated and justified.
	Final average result of repeated trials is used for plotting graphs not individual trials.
	Significant figures and units are used correctly in calculations. One extra significant figure is kept throughout the entire calculation to reduce rounding errors. The final result is consistent with the number of significant figures in the experimental measurements and any subsequent calculations based on them.

Presenting processed data

	Processed data and/or conclusions are summarized in a table or in some other easily interpretable manner so that all the stages to the final result can be followed.
	<p>Graphs should:</p> <ul style="list-style-type: none"> • have the axes labeled with the independent variable on the x axis and the dependent variable on the y axis • include units of measurement for each variable in brackets • have an appropriate scale for the data • be an appropriate size (at least ½ page) • have key/legend for two or more sets of data on the same graph is clear (or series deleted from excel graphs if there is only one set of data) • be 11 -12 point font and a consistent font type for electronic graphs • be called a figure and numbered consecutively with a concise descriptive title that describes the dependent (x axis) and independent (y axis) underneath the graph • have accurately plotted data • be correctly placed in document. <p>NOTE: Electronic graphs must be individually formatted.</p>
	Graphs have appropriate best fit straight lines or smooth line connecting the points. Plotting scatter graphs with data point to data point connecting lines without a line is not appropriate. Uncertainty bars are not required but can be used.
	All non-tables (graphs/diagrams) are called a figure and numbered consecutively with a concise descriptive title that describes the dependent (x axis) and independent (y axis) underneath the graph
	Uncertainties are propagated through a calculation and expressed as percentages. Experimental uncertainty transformed to the \pm amount pertaining to the actual result. Uncertainty should be estimated if only one measurement is done. NOTE: Final average result of repeated trials is used for the calculation of experimental uncertainty.

6. Conclusion

	A statement is made that indicates whether the aim / purpose / research question were achieved. This is stated explicitly and relates back to the details of the aim.
	The hypothesis is restated (if there is one) and it is stated whether it was proven in the investigation. If it was proven incorrect rewrite it as a correct statement.
	A valid interpretation of the results is made. The results and/or procedure are not restated. Compare the expected (from the hypothesis) and actual results (found in the experiment) quantitatively by comparing different graphs or by describing the trends shown
	The results are compared quantitatively to the accepted value when possible by calculating the % Difference. $\% \text{ Error} = \left \frac{\text{Experimental} - \text{Accepted}}{\text{Accepted}} \right \times 100$
	Comment on the difference between the % Difference and % Uncertainty If the % Difference > % experimental uncertainty, systematic errors are the main source of error. If the % Difference < % experimental uncertainty, random errors are the main source of error. To overcome this problem the experiment needs to be repeated more times.

7. Evaluation

Evaluating the procedure and results

	Describe the sources of systematic error and/or random error encountered and difficulties with the control of variables. The sources of error should be obvious (not trivial) errors that can be eliminated. And could include any assumptions made which may affect the result. Comment on the limitation of the method chosen if appropriate.
	Describe the effect of the systematic error on the magnitude and direction (result too high or too low) on the final result.

Improving the investigation

	Suggest and explain feasible ways the investigation could be improved so there is more agreement with what is expected. These modifications should address ways to reduce the systematic and random errors described above, achieve better control of the variables, reduce approximations or provide better procedures for measurement. The modifications should address the precision, accuracy and reproducibility of the result. Improvements need to be specific (not vague) and realistic and lead to significant improvement in experimentation. They should not involve unavailable equipment or materials. Completing more trials is only a feasible improvement if it could improve the <i>reliability</i> of the results or reduce random errors. Obtaining better equipment, more practice, avoiding spillages and spending more time on the experiment are not feasible improvements. The best improvements are those that can be carried out with the current schools resources.
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General Directions

	Ideas are expressed concisely and their organization allows for easy interpretation. Written in passive voice. Instead of: We measured 50 ml of HCl _(aq) acid in a 100 ml cylinder, use: 50 ml of HCl _(aq) was measured in a 100 ml cylinder. Pronouns [I, we, us, you] are replaced with "the". Chemical substances are named correctly and vague nouns like it, the substance, they is avoided.
	Author's name, date practical work was completed in class and name of partner/s on top right hand corner. Pages are numbered with 1.5 spacing between text.